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UNDERGROUND HEATING OIL AND MOTOR FUEL TANKS

EXEMPT FROM REGULATION UNDER SUBTITLE I OF RCRA:

A STUDY FOR

REPORT TO CONGRESS

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DISCLAIMER

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EXECUTIVE SUMMARY

Subtitle I of the Resource and Conversation Act (RCRA) requires the U.S. Environmental Protection Agency to develop a national program for regulation of underground storage tanks (USTs). Subtitle I excludes from regulation nine types of underground tank systems including two that are the focus of this study:

- Tank systems used for storing heating oil for consumptive use on the premises where stored; and

- Farm or residential tank systems of 1,100 gallons or less capacity used for storing motor fuel for noncommercial purposes.[1]

This study was undertaken to comply with Section 9009 (d) and (e) of RCRA, which requires EPA to study the tanks listed above and to report to the President and Congress whether these underground tank systems (hereafter, referred to as exempt tank systems) should be subject to the provisions of Subtitle I.

To provide the necessary information required to respond to Congress, this investigation identifies the:

- Size and geographic location of the population of exempt tank systems;

- Extent that exempt tank systems are known to leak and an assessment of their potential to leak;

- Potential hazards to human health and the environment posed by releases of stored substances from exempt tank systems; and

- Extent of state and local regulation of exempt tank systems.

Study Approach

The background study was conducted in three stages. First, EPA assessed the size, geographic location, and other characteristics of the exempt heating oil and motor fuel tank population, including the extent of known releases from such tank systems, using standard survey research techniques. Second, this assessment was reviewed by federal and state government officials and underground storage industry representatives. Finally, additional analyses,

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[1] Subtitle I exempts these tank systems from regulation by excluding them from the definition of underground storage tanks (USTs). Therefore, when used in this report, the term UST refers only to underground storage tanks regulated under Subtitle I.

using supplemental data provided by these representatives, were thereafter conducted to address comments received from this review.

This study relies mainly on existing data. Some of the information obtained is useful to the analyses only if some reasonable assumptions are made. To the extent possible, petroleum and underground storage experts from both industry and government were contacted regarding the validity of the assumptions used.

The exempt tank systems addressed in this study are divided into two major types: motor fuel tank systems and heating oil tank systems. Exempt motor fuel tank systems are subdivided into tank systems located at (1) farms and (2) residences. Exempt heating oil tank systems are subdivided into tank systems used at (1) farms, (2) residences, and (3) nonresidential facilities. Residential facilities include apartment complexes, condominiums, townhouses, and single-family homes. Nonresidential facilities include commercial, institutional, government, manufacturing, and military facilities. The distinction between motor fuels and heating oils and the breakdown of sectors among farms, residences, and nonresidential facilities correspond generally to the language of the statutory exemption in this study.

Characteristics of the Population of Exempt Tank Systems

The estimated population of exempt tank systems in the United States is about 3.1 million tanks, almost twice the number of USTs currently regulated under Subtitle I (1.7 million). The 3.1 million total population of exempt tanks breaks down into the following sectors[2]:

<u>Heating Oil Tanks (2.7 million tanks)</u>

(1) Residential sector: 1.9 million tanks (61%)

(2) Nonresidential sector: 0.8 million tanks (25%)

(3) Farm sector: 0.04 million tanks (1%)

<u>Motor Fuel Tanks (0.4 million tanks)</u>

(1) Farm sector: 0.3 million tanks (10%)

(2) Residential sector: 0.1 million tanks (3%)

Geographically, heating oil tank systems are concentrated in the Northeast, where fuel oil is commonly used for heating; relatively few exempt

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2 The precession and accuracy of these estimates could not be defined quantitatively. Data quality objectives were set at the beginning of this study assuming that if tank system estimates are within a factor of two of the true population size, the errors in the estimates would not significantly affect the regulatory decisions to be made as a result of this report.

heating oil tank systems are located in the West. This observation applies especially to residential heating oil tank systems. Farm heating oil tank systems are more uniformly distributed throughout the country. Exempt farm motor fuel tank systems are concentrated in the North Central and West; the Northeast contains the fewest of these tank systems. The geographic concentration of exempt residential motor fuel tank systems could not be established with available data.

The technical and operational characteristics of exempt heating oil and motor fuel tank systems are better understood if they are compared and contrasted to those of regulated USTs. The similarities and differences between exempt tank systems and regulated USTs are summarized below.

Similarities:

- Most exempt tank systems and regulated USTs are constructed of steel and are not protected against corrosion;
- Existing exempt tank systems and regulated USTs have similar age distributions (most of them are over 15 years old); and
- Exempt nonresidential heating oil tanks are similar to regulated tanks in size and gauge (thickness) of steel.

Differences:

- Most exempt residential and farm tank systems have a storage capacity of less than 1,100 gallons. These tanks, therefore, tend to be much smaller and made of lighter-gauge steel than most regulated USTs;
- Although most exempt tank systems store heating (87 percent, based on our population estimates) most regulated USTs store motor fuels;
- Although exempt tank systems use suction pumps, about one-half of the regulated USTs (including most of the retail motor fuel facilities) use pressurized pumps. The use of suction pumps results in negative pressure on the feed lines, and, if a leak occurs, air and water are drawn in, instead of product being pumped out; and
- Effective methods of leak prevention and detection are less commonly an integral part of exempt nonresidential tank systems, compared to regulated USTs and are seldom a part of small exempt residential or farm tank systems.

Extent of and Potential for Releases

The annual rate of reported releases from exempt tank systems has increased significantly over the last 17 years. For example, the number of reported releases from exempt tank systems in just three states in a recent 2-year period (1985-1987) exceeds the number of reported incidents in EPA's National Data Base for the entire nation over the previous 15 years.

Documented data, case histories, and other information collected during this investigation lead to the following observations:

- Reports of releases from regulated USTs are more common than reports of releases from exempt tank systems. Differences in release detection and reporting may account for some of this disparity.

- Reports of releases from exempt tank systems most frequently occur in the Northeast and involve release of fuel oil No. 2.

- Nearly 80 percent of reported releases from exempt tank systems are from nonresidential tank systems, even though this sector comprises only 25 percent of the exempt tank systems that are subject to this study. Differences in release detection and reporting may account for some of this disparity.

- Some exempt tank system releases have occurred over a long time and the effects from some releases have persisted in the environment for years despite attempted corrective actions.

- The material of construction for exempt nonresidential tank systems is similar to regulated USTs. Exempt residential tank systems, however, tend to be made of thinner and lighter-gauge steel.

- The age, cause of release, and reported release quantities are similar for exempt tank systems and regulated USTs.

As a result of their similar characteristics, the potential for exempt tank systems and regulated USTs to leak is likely to be similar if they are not protected against corrosion.

Potential Impacts to Human Health

Exempt heating oil and motor fuel tank systems are used to store a variety of petroleum products, including gasoline and diesel fuel (motor fuels), and fuel oils Nos. 1, 2, 4, 5, and 6 (heating oils). With the exception of gasoline, the toxicities of these fuels have not been well studied and only limited information regarding the fuels as mixtures is available. Gasoline, which has been the subject of extensive study under RCRA's Subtitle I regulatory program, is already classified as a probable human carcinogen. Consequently, the discussion of potential impacts to human health in this study focuses primarily on heating oils, the petroleum products stored most frequently in exempt tank systems.

All of the products stored in exempt heating oil and motor fuel tanks contain noncarcinogenic substances that can cause adverse health effects. In addition, some of the products contain known or probable carcinogens; however, the exact concentrations of the hazardous substances present in these products are unknown. The principal routes of human exposure to releases are through contamination of air, soil, surface water, and, most significantly, ground water. Although the exact level of risk posed by releases of these products is difficult to assess, relative risks can be assessed based on the toxicity of the product and its constituents, and the likelihood of the products to contaminate soil, ground water, and air.

- Contaminated ground water is the most likely route of human exposure to products released from exempt tank systems. Consumption of ground water with low levels of contaminants may continue for long periods of time and thus represents the most significant threat to human health. High levels of contamination are less of a problem because people are less likely to drink water that has a bad taste or smell.

- Gasoline is the most studied fuel stored in exempt tank systems. Gasoline is likely to travel faster in the soil than other products stored in exempt tanks systems and is a probable human carcinogen.

- Of the heating oils, the middle distillates, such as fuel oil No. 2, probably pose the greatest threat to human health. These products are slightly less mobile than gasoline, but are still likely to contaminate ground water. In addition, low levels of probable carcinogens have been detected in fuel oil No. 2. The middle distillates also contain other substances known to have adverse health effects.

- Residual fuels, such as fuel oil No. 6, probably pose the smallest threat to human health, but this threat may still be significant. Even though fuel oil No. 6 contains relatively high levels of cancer-causing substances, it can have such a high viscosity (resistance to flow) that it is unlikely to reach ground water in large quantities. However, under certain conditions, such as fuel oil No. 6 released near a sewer line or into fractured bedrock, large amounts of contamination have occurred. Furthermore, although residual fuels are not as mobile as the middle distillates, they are difficult to clean up after a release and are likely to persist in the environment longer than other fuels.

State and Local Regulation of Exempt Tank Systems

During February 1988, EPA examined statutes and regulations from 34 states to determine the current level of regulation of exempt heating oil and motor fuel tank systems by states (the remaining 16 states did not have UST statutes available for review). This review revealed that at least 21 states currently consider exempt tank systems to be a problem and, have included them to some extent in their regulatory framework. Of the 34 states reviewed:

- Twenty states have some regulations for exempt heating oil tank systems (panel 1 of Exhibit 5-1);

- Ten states have some regulations for exempt motor fuel tank systems (panel 2 of Exhibit 5-1);

- Six states have some regulations for all exempt tank systems (panel 3 of Exhibit 5-1); and

- Thirteen states have no regulations for exempt heating oil and motor fuel tank systems (panel 4 of Exhibit 5-1).

Although some states require only that owners and operators of exempt tank systems report and clean up releases, others impose a variety of technical standards (such as material of construction and leak detection). Many of the state regulations governing exempt heating oil tank systems, however, cover only those tank systems with a capacity equal to or greater than a specified size, most commonly 1,100 gallons.

State regulation of exempt tank systems was generally more extensive in those states where the greatest number of exempt tank systems are located. For example, all of the states in the Northeast, except Pennsylvania and Delaware, have some regulations regarding exempt heating oil tank systems (exempt heating oil tank systems located in the Northeast comprise almost 50 percent of all exempt tank systems).

1. BACKGROUND AND STUDY APPROACH

Subtitle I of the Resource and Conversation Act (RCRA) requires the U.S. Environmental Protection Agency to develop a national program for regulation of underground storage tanks (USTs). Subtitle I excludes from regulation nine types of underground tank systems including two that are the focus of this study:

- Tank systems used for storing heating oil for consumptive use on the premises where stored; and
- Farm or residential tank systems of 1,100 gallons or less capacity used for storing motor fuel for noncommercial purposes.[1,2]

This study was undertaken to comply with Section 9009 (d) and (e) of RCRA, which requires EPA to study the tanks listed above and to report to the President and Congress whether these underground tank systems (hereafter, referred to as exempt tank systems) should be subject to the provisions of Subtitle I.

This report is divided into five sections. The following sections of this study address the questions below:

<u>Section 2</u>. Description of Exempt Heating Oil and Motor Fuel Tank Systems

- What is the size of the population of exempt tank systems?
- What is the geographic distribution of that population?
- What characteristics of exempt tank systems affect their likelihood to leak?

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[1] The following structures or tank systems are also excluded from regulation under Subtitle I, but are not addressed in this study: septic tanks; pipeline facilities regulated under certain other federal and state laws; surface impoundments, pits, ponds, or lagoons; storm water or wastewater collection systems; flow-through process tanks; liquid traps or associated gathering lines directly related to oil or gas production and gathering operations; or storage tanks situated on or above the surface of the floor in underground areas. Subtitle I exempts these tanks by excluding them from the definition of underground storage tanks (USTs). When used in this report, the term "exempt tank system" refers only to exempt heating oil and motor fuel tanks, while the term "regulated UST" refers only to underground storage tanks regulated under Subtitle I.

[2] Definitions for underground storage tank, regulated substances, tanks, tank systems, and exempt heating oil and motor fuel tank systems are provided in Appendix E.

Section 3. Extent of Releases from Exempt Heating Oil and Motor Fuel Tank Systems

- To what extent do exempt tank systems presently leak?
- What is the potential for releases from exempt tank systems?

Section 4. Potential Impacts on Human Health of Products Released from Exempt Heating Oil and Motor Fuel Tank Systems

- What adverse health effects have been associated with exposure to products stored in exempt tank systems?
- How are released products transported through the environment?
- What are the potential health risks associated with exposures to products released from exempt tank systems?

Section 5. State and Local Regulation of Exempt Heating Oil and Motor Fuel Tank Systems

- To what extent do state and local governments currently regulate exempt tank systems?

In addressing these questions, this study compares its findings with similar information regarding USTs regulated under Subtitle I.

The exempt tank systems addressed in this study are divided into two major types: motor fuel tank systems and heating fuel tank systems. Exempt motor fuel tank systems are subdivided into tank systems located at farms and those located at residential buildings. Exempt heating oil tank systems are subdivided into tank systems located at farms, at residences, and at nonresidential facilities. Residential facilities include such residential units as apartment complexes, condominiums, townhouses, and single-family homes. Nonresidential facilities include tank systems located at commercial, institutional, government, manufacturing, and military facilities. The distinction between motor fuels and heating oils and the breakdown of sectors among farms, residences, and nonresidential facilities in this study corresponds with the language of the statutory exemption.

This study was conducted in three stages. First, EPA assessed the size, geographic location, and other characteristics of the population of exempt tank systems, including the extent of known releases from these tanks, using standard survey/research techniques. Second, this information was reviewed by federal and state government officials, and underground storage tank systems industry representatives. Third, the information and comments received from these individuals were assessed, and additional analyses were performed on data that was obtained from underground tank systems and petroleum industry representatives and government officials, to address comments made regarding:

- Size of the population of exempt tank systems and how it was estimated;

- Differences among use sectors and among various fuels stored in exempt tank systems;

- Potential for exempt tank systems to leak, including the principal causes;

- Fate and transport of released product in the environment; and

- Potential hazards to human health and the environment posed by released products.

This study relies mainly on existing data. Additional information was obtained from states and other readily available sources, but no new surveys were conducted. Some of the additional information obtained was useful in the analyses only if some reasonable assumptions were made. To the extent possible, underground tank systems and petroleum experts from both industry and government were contacted regarding the validity of the assumptions used. Each section of this document includes a brief description of the methods and assumptions used. The specific sources of data and analytic procedures used are described in the Appendices.

2. DESCRIPTION OF EXEMPT HEATING OIL AND MOTOR FUEL TANK SYSTEMS

This section presents information on the universe of exempt tank systems,[3] including the size of the population (Section 2.1); geographic location (Section 2.2); technical characteristics (Section 2.3); current management practices (Section 2.4); and summary findings (Section 2.5).

2.1 SIZE OF THE POPULATION

The estimated total population of exempt heating oil and motor fuel tank systems in the United States is 3.1 million, almost twice the number of USTs currently regulated under Subtitle I (Exhibit 2-1). The exempt tank systems population consists of 2.7 million tanks storing heating oil and 0.4 million tanks storing motor fuel. Estimates of the size of the population for the three sectors of exempt heating oil tank systems and two sectors of exempt motor fuel tank systems are presented in Sections 2.1.1 and 2.1.2, respectively.

The precision and accuracy of these estimates could not be defined quantitatively. Data quality objectives were set at the beginning of this study assuming that if tank system estimates are within a factor of two of the true population size, the errors in the estimates would not significantly affect the regulatory decisions to be made as a result of this report. A discussion of the sources of data, the methodology used, and an assessment of the factors potentially affecting the accuracy of the estimates of the population size is presented in Sections A.1 and A.2 of Appendix A.

2.1.1 Exempt Heating Oil Tank Systems

Residential Heating Oil Sector

The size of the exempt residential heating oil tank system population is estimated to be 1.9 million tank systems, which include an estimated 1.6 million single-family residential tank systems and 0.3 million multiple-family tank systems. These numbers were derived from estimates of housing units using heating oil and the estimated probability that these heating oil tanks are buried underground. U.S. Census data were used to estimate the number of housing units. The probability that heating oil tanks are buried underground was derived from contacts with industry representatives (see Exhibit A-4 of Appendix A; and PMAA 1987). Additional information on these estimates is provided in Section A.1.1 of Appendix A.

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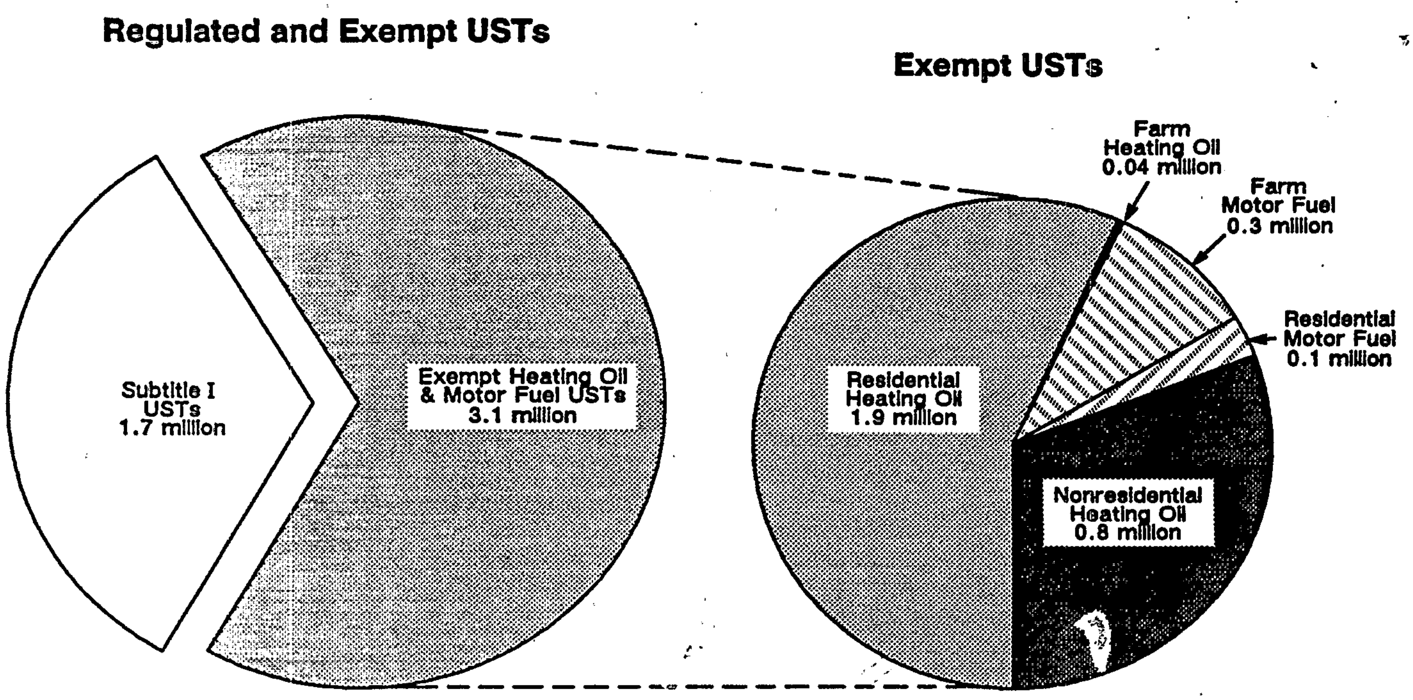
3 An exempt tank system includes a single exempt tank and its associated piping. Further elaboration of this definition and other definitions, including heating oil and motor fuel tank systems, are found in Appendix E.

Exhibit 2–1

Population Size of Exempt and Regulated USTs



Source: See appendix A for sources and derivations.

Farm Heating Oil Sector

The estimated size of the exempt underground farm heating oil tank system population is 0.04 million tanks, as reported by the 1985 Farm Costs and Returns Survey (U.S. Department of Agriculture, unpublished data). Some of these tank systems could also be included in the estimate of residential heating oil units in the U.S. Census, because owners and operators could have reported their tank systems as both residential and farm tanks. The effect of this potential overlap on the national estimate of the entire exempt tank system population is minimal, because the entire farm heating oil sector comprises only 1 percent of the total estimated number of exempt tanks (Exhibit 2-1). (Additional information on this estimate appears in Section A.1.2 of Appendix A.)

Nonresidential Heating Oil Sector[4]

There are an estimated 0.8 million exempt nonresidential heating oil tank systems. This number was determined by adding estimates for three individual subsectors (commercial, institutional, and government facilities; manufacturing facilities; and military facilities). Estimates of this exempt tank system population and the general methods used to derive the estimates for each of the subsectors are provided below. (Additional information on these estimates is provided in Section A.1.3 of Appendix A.)

<u>Commercial, Institutional, and Government Tank Systems</u>. There are an estimated 0.54 million exempt heating oil tank systems in the commercial, institutional, and government subsector. This number was estimated based on the number of heating oil tanks (including both aboveground and underground tanks) identified in the Non-Residential Buildings Energy Consumption Survey (U.S. Department of Energy 1985). This survey includes estimates of the number of buildings with heating oil as an energy source, the number of heating oil tanks, and the total tank capacity. To estimate the population of this subsector that is buried underground, the probability of a heating oil tank being buried, based on both tank and building size, was multiplied by the estimated number of heating oil tanks. The probability that a tank is buried underground was derived from contacts with industry representatives (see Exhibit A-4 of Appendix A; and PMAA 1987).

<u>Manufacturing Tank Systems</u>. There are an estimated 0.19 million exempt heating oil tank systems located at manufacturing facilities. There were no Census or survey data available for directly estimating the number of exempt manufacturing heating oil tank systems; therefore, the estimated total storage capacity for heating oils stored for consumptive use at manufacturing facilities (obtained from the National Petroleum Council 1984) was divided by an estimate of the average tank capacity of manufacturing heating oil tanks (including both aboveground and underground tanks) to determine the number of manufacturing heating oil tanks. The number of tanks that are buried

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4 Nonresidential exempt heating oil tanks include tanks located at commercial, institutional, government, manufacturing, and military facilities (but not farms).

underground was then estimated by multiplying the number of storage tanks by the percentage assumed to be buried (see Exhibit A-4 of Appendix A; and PMAA 1987).

Military Tank Systems. There are an estimated 0.06 million exempt heating oil tank systems owned by the military services, according to information obtained from the four military services. An estimated 0.042 million heating oil tank systems are used to heat military residential facilities. The number of exempt tank systems used to heat nonresidential buildings could not be directly estimated. However, according to the military services, three-quarters of all military heating fuel tank systems are associated with housing, which implies that there are an additional 0.014 million tanks for heating nonresidential military buildings. Thus, the total number of exempt tank systems owned by the military was estimated to be 0.056 million tank systems (or 0.06 million after rounding). A breakdown of the number of exempt residential heating oil tank systems reported by each military service is provided in Section A.1.3 of Appendix A.

2.1.2 Exempt Motor Fuel Tank Systems

Farm Motor Fuel Sector

There are an estimated 0.3 million exempt farm motor fuel tank systems. The number of these tank systems has been estimated by two separate surveys: the 1985 Farm Costs and Returns Survey (U.S. Department of Agriculture, unpublished data) and the Motor Fuels Storage Tanks Survey (USEPA 1986a). The 1985 Farm Costs and Returns Survey estimated a total of 0.37 million farm motor fuel tank systems. The Motor Fuels Storage Tanks survey estimated a total of 0.16 million of these tank systems. The average of these two estimates -- 0.26 million tanks -- was selected as the best estimate of the number of farm motor fuel tank systems. (Additional information on this estimate appears in Section A.2.1 of Appendix A.)

Residential Motor Fuel Sector

There are an estimated 0.2 million exempt residential motor fuel tank systems. No published Census or survey data exists from which estimates of the number of exempt residential motor fuel tank systems could be directly made. Three states (California, Maine, and Wisconsin), however, require registration of all exempt motor fuel tank systems and reported a total of 12,409 exempt motor fuel tank systems in their UST notification data bases. The mean of the ratio of the number of exempt motor fuel tank systems to the number of housing units for each state was used to extrapolate the number of exempt residential motor fuel tank systems nationwide. This ratio was multiplied by the estimated number of housing units in the U.S. Census. This extrapolation is described in Section A.2.2 of Appendix A.

2.2 GEOGRAPHIC LOCATION

The geographic location of the exempt tank systems in the three heating oil sectors and the farm motor fuel sector was determined using the same methodology that was employed for the national population estimate; however, regional data were substituted for national population aggregate data in the calculations presented in Appendix A. The four geographic regions depicted in Exhibit 2-2 represent the regional classifications used by the U.S. Census. The geographic location of the final sector, exempt residential motor fuel tank systems, could not be properly determined, because the national estimate is based on data from just three states.

Exhibit 2-2 illustrates the regional location of exempt tank systems. Heating oil tank systems, especially residential heating oil tank systems are concentrated in the Northeast; relatively few are located in the West (Exhibit 2-3). Farm heating oil tank systems are more uniformly distributed throughout the country. Exempt farm motor fuel tank systems are concentrated in the North Central and West; the Northeast contains the fewest of these tank systems.

2.3 TECHNICAL CHARACTERISTICS

Five categories of technical characteristics for exempt tank systems are described in this section: (1) system description; (2) construction material; (3) age; (4) capacity; and (5) contents. Data on the first and fifth categories were obtained from interviews with representatives of the underground storage tank and petroleum industries.[5] Data on the second, third, and fourth categories were obtained from the state UST notification data bases for California, Montana, and Maine[6] and from interviews with UST program officials in Connecticut, Kansas, Massachusetts, Minnesota, and North Carolina (CDEP 1986; KDHE 1986; MDEQE 1986; MPCA 1986; and NCDNRCD 1986). The number of tank systems registered in the California, Montana, and Maine state notification data bases at the time of this study is presented in Section A.3 of Appendix A.

2.3.1 System Description

This section describes the major components of typical exempt tank systems based on information obtained from underground storage tank and petroleum industry representatives. A detailed description is provided for typical exempt residential or farm heating oil tank systems and these systems are compared to other exempt tank systems and regulated USTs.

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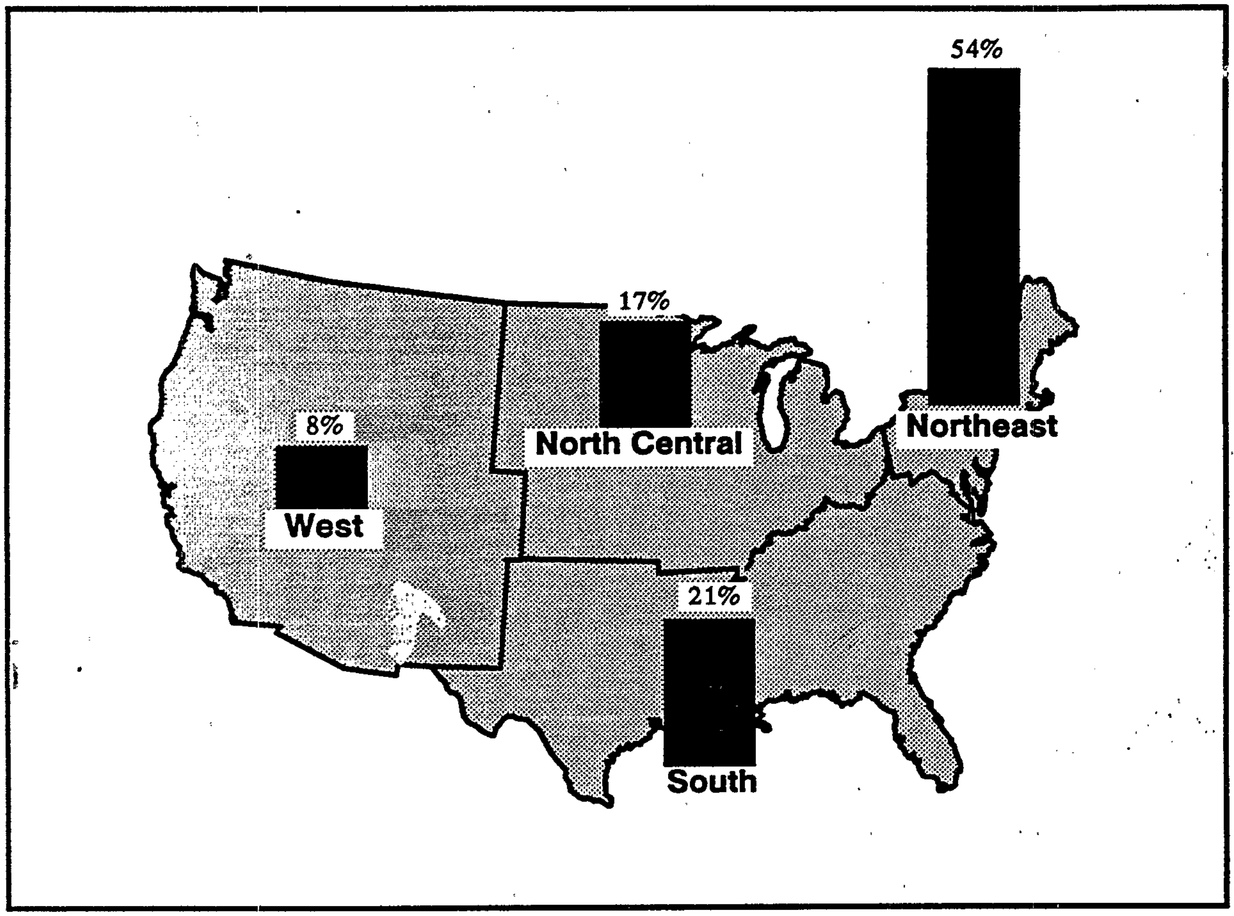
[5] The information was obtained during spring, 1988, from discussions between Midwest Research Institute and representatives of Besche Oil (Waldorf, MD), Bridgeport Testing Lab Chemicals (Bridgeport, CT), Buffalo Tank (Baltimore, MD), T.W. Perry (Gaithersburg, MD), Shreve Fuel (Arlington, VA), and Southern Maryland Oil (La Plata, MD).

[6] These three states require registration of both exempt tank systems and regulated USTs. Although some other states have similar requirements, data were not available.

Exhibit 2–2

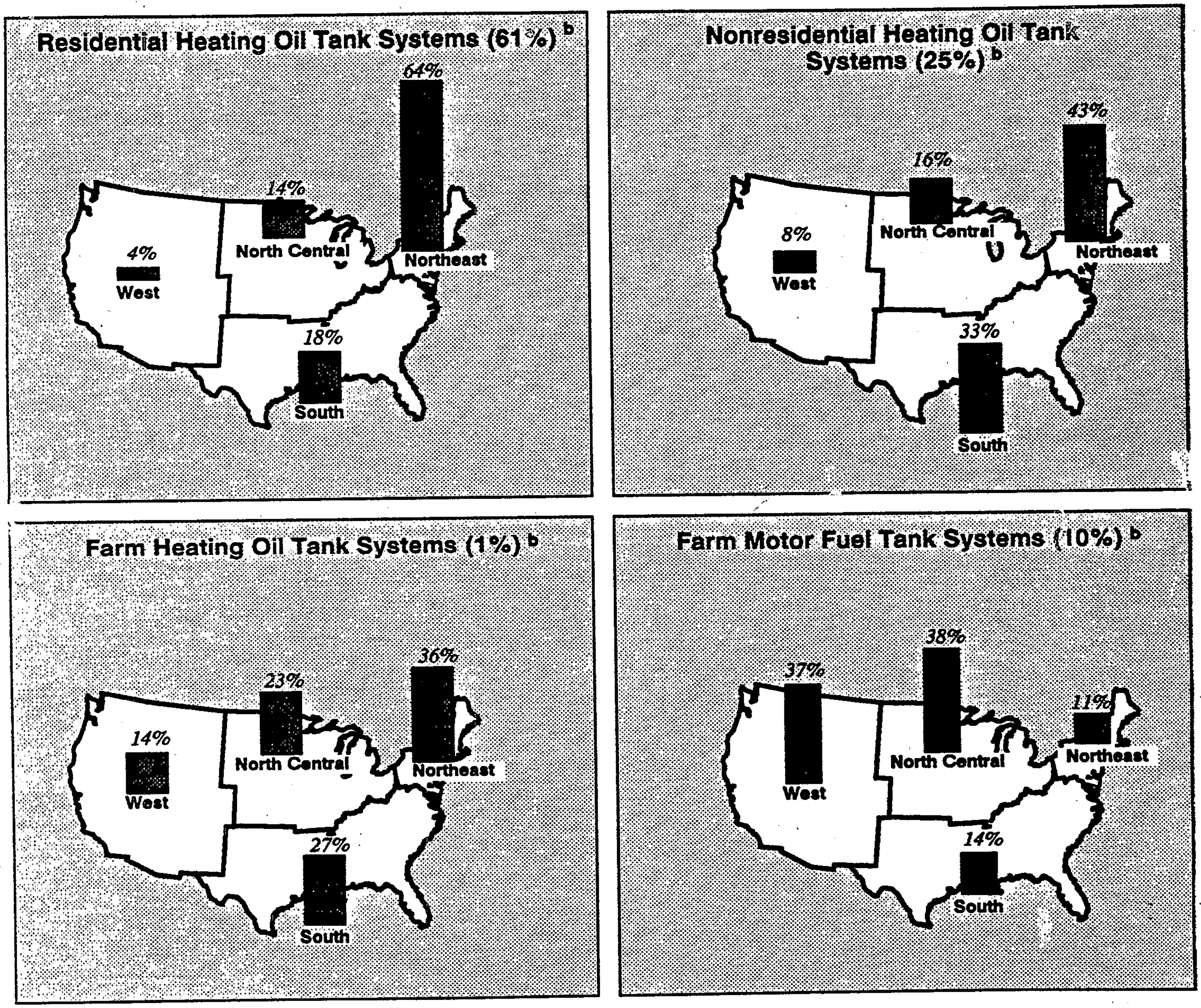
Geographic Concentration of Exempt Heating Oil and Motor Fuel Tank Systems [a]



[a] Totals for the West include Alaska and Hawaii.

Exhibit 2–3

Geographic Concentration of Exempt Heating Oil and Motor Fuel Tank Systems by Use Sector[a]



See Appendix A for sources and derivations.

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[a] Totals for West include Alaska and Hawaii.

[b] Numbers in parentheses are the percentage that each use sector contributes to the universe of exempt heating oil and motor fuel tank systems.

Residential and Farm Heating Oil Tank Systems

Residential and farm heating oil tank systems are commonly designed by the fuel oil supplier to meet customer needs and local regulatory requirements. Tanks are usually installed close to the residence (i.e., within 6 feet) and are covered with approximately two feet of soil. Some contractors use select backfill materials, such as sand, but most simply refill the excavation with the native soil.

A typical residential or farm heating oil system includes a bare steel tank (usually less than 1,000 gallons in capacity), a vent pipe, a fill pipe, and a feed line to the burner (furnace). Most systems also have a return line from the burner to the tank to return unused oil. Most new installations use 1/4- or 3/8-inch diameter, soft, rolled copper piping for the feed and return lines in order to minimize the number of joints needed. Older systems commonly use 1/2-inch diameter carbon steel piping. The fill and vent lines are generally made of galvanized or coated and wrapped carbon steel with a diameter of 1 1/4 or 1 1/2 inches. A diagram of a typical residential or farm heating oil tank system is shown in Exhibit 2-4.

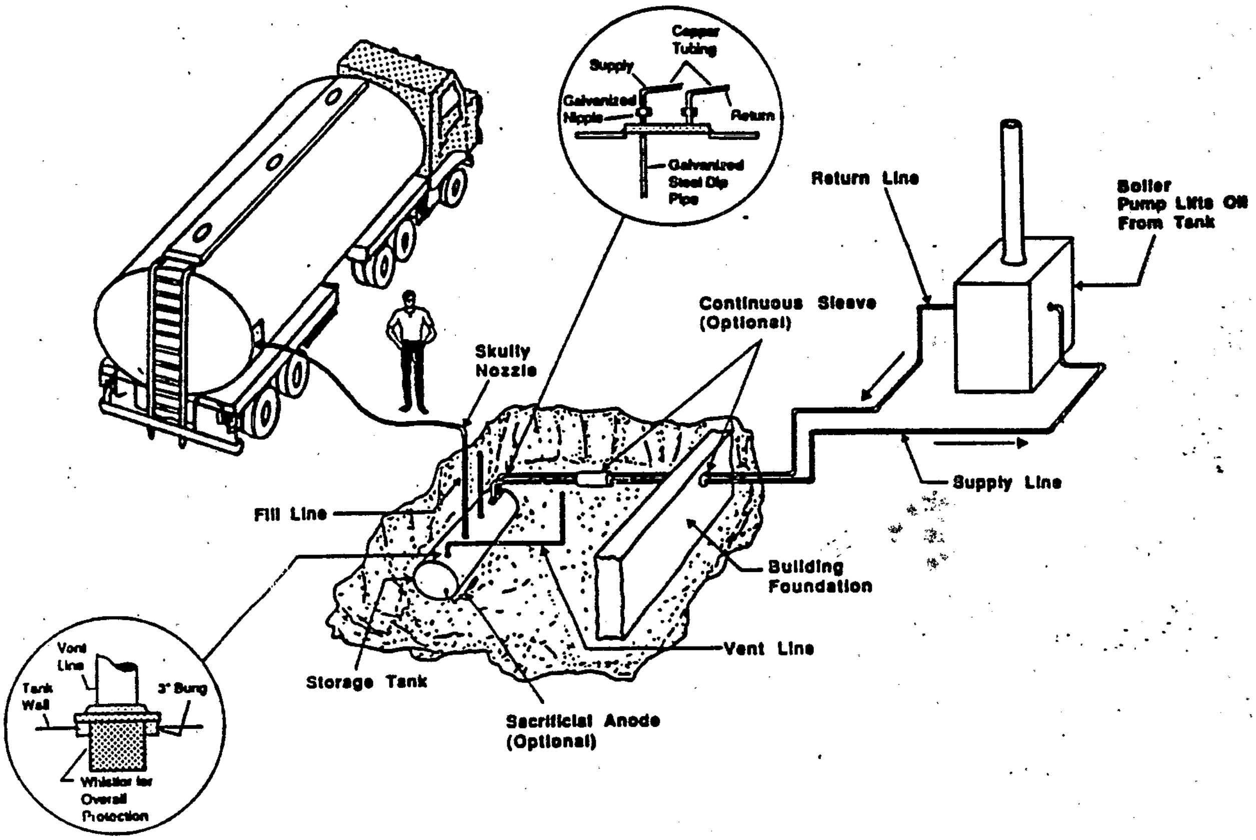
Residential and farm heating oil tank systems usually use a suction pump located at the burner to lift or pull heating oil No. 2 from the tank to the burner. This results in a low (5-10 PSIG) negative pressure on the feed line and a low (5-10 PSIG) positive pressure on the return line. If the feed line develops a leak, it will tend to draw air or water into the system, rather than forcing heating oil out of the pipe. The presence of excess air or water in the feed line can result in the fouling of the burner, a condition that can signal to tank owners that they have a problem with their tank system. A nontight return line, on the other hand, will tend to force unused oil out of the pipe under low pressure; such a leak can be difficult to detect.

Heating oils and motor fuels are usually delivered by 2,500 to 3,000-gallon trucks. Product is commonly delivered from the truck to the tank through a 1 1/4-inch industrial hose with a "Scully" nozzle on the end that attaches to the tank's fill nozzle. The nozzle couples tightly with the fill pipe, but is capable of popping free if back pressure is encountered. Alternatively, a "tight fit" nozzle, which locks to the fill pipe and will not release in the event of back pressure, is sometimes used. A "tight fit" nozzle can overpressure and rupture a tank if the vent line is clogged.

Vent piping, which allows the tank to breathe, allows air to escape from the tank when it is being filled and to enter the tank while oil is being withdrawn. In some systems, a device referred to as a "whistler" is installed in the vent line to prevent overfilling (refer to Exhibit 2-4). As air is forced out of the tank during the filling operation, the unit produces a whistling noise. When the fluid reaches the device, the noise ceases and the delivery is stopped. Heating oil distributors report that spills from overfilling are small (less than one-gallon) if a Scully nozzle is used and a whistler is present in the vent line.

Exhibit 2-4

Typical Exempt Residential or Farm Heating Oil Tank System



Source: Midwest Research Institute, Spring 1988.

Nonresidential Heating Oil Tank Systems

The components for small nonresidential heating oil systems are very similar to those of residential and farm heating oil systems, but become more complex for larger facilities. Medium-sized nonresidential facilities differ from residential and farm heating oil tank systems mostly by using larger tanks and piping. Large facilities (such as industrial operations, manufacturing plants, and military bases) may use large tanks (5,000 to 100,000 gallons) or multiple tank systems manifolded together, and tend to have larger (2- to 4-inch diameter), more complex, and longer piping that operates under higher pressure (pressures up to 200 PSIG are not uncommon). A diagram of one possible large nonresidential heating oil tank system is shown in Exhibit 2-5.

It is often more economical for larger heating oil systems to use residual heating oils (a lower grade of heating oil than fuel oil No. 2, including fuel oil Nos. 5 and 6 and most blends of fuel oil No. 4). The use of residual fuels requires some specialized tank system equipment, including differences in: (1) burner types for atomizing the fuel prior to its burning and (2) tank heaters and pumps that, depending on the climate and characteristics of the particular fuel used, improve the ability of the fuel to flow within the tank system.

Residential and Farm Motor Fuel Tank Systems

Exempt residential and farm motor fuel systems have a capacity of 1,100 gallons or less and are similar to smaller heating oil systems. Most of these tank systems have similar components to residential and farm heating oil systems. Piping systems are electrically grounded to prevent fires, and whistlers are not used in the vent lines because of potential fire and explosion hazards. Most jurisdictions require some type of tank permit from the local fire department. A typical residential or farm motor fuel system is shown in Exhibit 2-6.

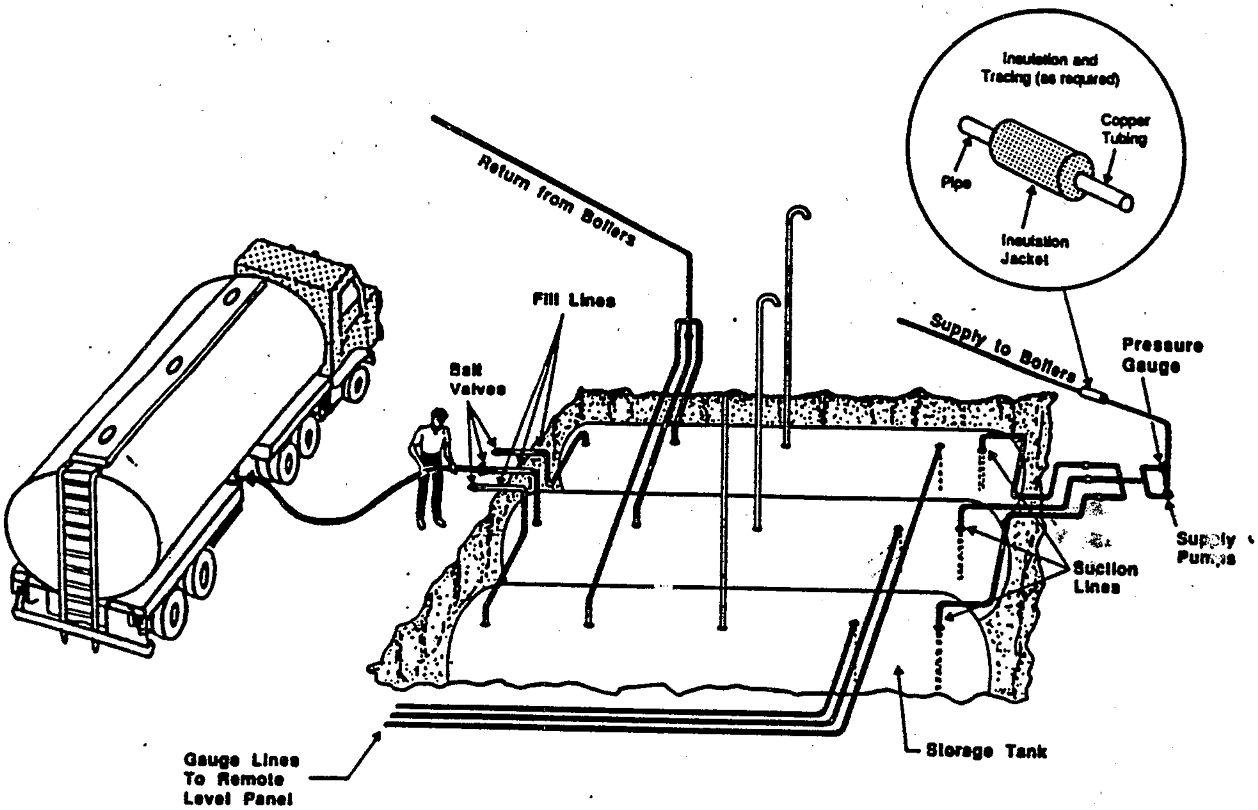
Comparisons Between Exempt Tank Systems and Regulated USTs

Exempt tank systems have many characteristics in common with the regulated USTs, as well as some significant differences. Similarities include some essential system components -- the tank, piping, and a pump. Differences include the size of the tank and pipes, type of pump, and operating characteristics. This discussion highlights some of the key similarities and differences between these two populations.

Exempt residential and farm tank systems are generally much smaller and have thinner-walled tanks, particularly for heating oil tank systems, than either exempt nonresidential tank systems or regulated USTs. Thinner-walled tanks appear to be more susceptible to external corrosion and tank leakage. In contrast, the common sizes of tanks and piping used for exempt nonresidential tank systems are similar to those commonly used by regulated USTs.

Exhibit 2–5

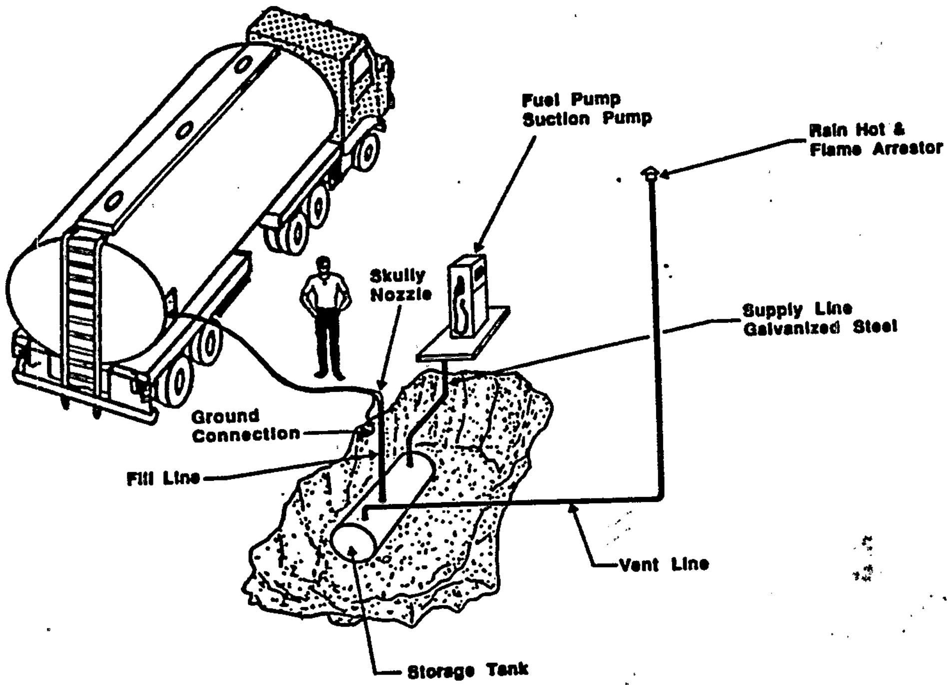
One Possible Large Exempt Nonresidential Heating Oil Tank System



Source: Midwest Research Institute, Spring 1988.

Exhibit 2–6

Typical Exempt Residential or Farm Motor Fuel Tank System



Source: Midwest Research Institute, Spring 1988.

Exempt residential and farm tank systems typically have fewer and shorter pipes that are less complex than other exempt tank systems or regulated USTs. Regulated USTs, as represented by a motor fuel retail facility, tend to have a complex system of pipes to manifold multiple tanks together.

Regulated USTs most frequently use pressure pumps, whereas exempt tank systems (especially residential, farm, and small nonresidential tank systems) use suction pumps. The use of pressure pumps results in positive pressures on motor fuels in the piping, which increase the rate of product released if structural failure, loose couplings, or corrosion breakthrough occurs. The use of suction pumps, particularly for residential and farm heating oil tank systems, results in a negative pressure in the feed line and a small positive pressure in the return line. If structural failure, loose couplings, or corrosion occurs on the feed line of a heating oil tank system, air or water tends to be drawn in, rather than stored product being forced out. The positive pressure on the return line of exempt tank systems would typically be less than that of regulated USTs. This lower pressure, along with heating oil's greater resistance to flow compared to gasoline, reduces the rate at which stored product is released from exempt tank systems.

Finally, regulated USTs more often have some type of built-in leak detection than do exempt tank systems, especially residential and farm tank systems.

2.3.2 Construction Material

Most exempt tank systems are constructed of steel (Exhibit 2-7). More exempt residential and farm heating oil and motor fuel t nk systems are made of steel than are exempt nonresidential heating oil tank systems, according to information obtained from California and Maine. A high proportion of steel tanks was also reported by UST program officials from Connecticut, Kansas, Massachusetts, Minnesota, and North Carolina, who estimated that over 95 percent of exempt tank systems in their states were constructed of steel. In comparison, it is estimated that 89 percent of USTs regulated under Subtitle I are made of steel (ICF 1988a).

In California, fiberglass-reinforced plastic (FRP) tank systems were more frequently used than in Maine or Montana, particularly for USTs regulated under Subtitle I. The higher proportion of FRP tank systems in California may be a result of relatively stringent state regulation of both federally regulated USTs and exempt tank systems compared to other states (see Section 5).

2.3.3 Age

Approximately one-third to one-half of exempt tank systems in California, Maine, and Montana are over 16 years old (Exhibit 2-8). Exempt nonresidential tank systems are older than exempt residential or farm tank systems in California and Maine.

EXHIBIT 2-7

COMPARISON OF CONSTRUCTION MATERIAL
FOR EXEMPT TANK SYSTEMS AND REGULATED USTs

(Percent of Registered Tank Systems)

	Exempt Tank Systems			Regulated USTs
	Heating Oil		Motor Fuel	
	Farm or Residential	Nonresidential		
California:				
Steel	87	78	87	81
FRP	0	10	1	10
Other	13	12	12	9
Maine:				
Steel	99	92	99	95
FRP	<1	8	<1	5
Other	<1	<1	0	<1
Montana:				
Steel	--------------99--------------		99	97
FRP	--------------0--------------		<1	<1
Other	--------------<1--------------		<1	2

Source: State UST Notification Data Bases from: California State Water Resources Control Board, Dec. 1986; Maine Dept. of Environmental Protection, Dec. 1986; and Montana Dept. of Health and Environmental Science, March 1987.

EXHIBIT 2-8

COMPARISON OF AGE OF EXEMPT TANK SYSTEMS AND REGULATED USTs

(Percent of Registered Tank Systems)

Tank Age (years)	Exempt Tank Systems: Heating Oil[b] Farm or Residential	Exempt Tank Systems: Heating Oil[b] Nonresidential	Exempt Tank Systems: Motor Fuel	Regulated USTs[a]
≤5	10	8	10	16
6-10	27	22	27	21
11-15	27	18	25	21
16-20	12	12	14	18
>20	24	40	24	24
Totals	100	100	100	100

Source: State UST Notification Data Bases from: California State Water Resources Control Board, Dec. 1986; Maine Dept. of Environmental Protection, Dec. 1986; and Montana Dept. of Health and Environmental Science, March 1987.

[a] Data on regulated USTs in the Regulatory Impact Analysis are slightly, but not significantly different (ICF 1988a).

[b] Data for heating oil tanks includes data only from California and Maine. The Montana data base did not contain sufficient data on facility type to analyze by use sectors.

The age of exempt residential and farm tank systems is very similar to the age of USTs regulated under Subtitle I in these states (Exhibit 2-4). However, in California and Maine there is a larger proportion of exempt nonresidential heating oil tank systems over 20 years old compared to USTs regulated under Subtitle I.

2.3.4 Capacity

Of the exempt farm and residential heating oil tank systems located in California or Maine, 88 percent had a capacity less than or equal to 1,100 gallons (Exhibit 2-9). Exempt motor fuel tank systems, by statutory definition, must all be under 1,100 gallons in capacity. In contrast, the capacity of nonresidential heating oil tank systems in these states is generally much larger and highly variable.

Exempt residential and farm tank systems storing either heating oil or motor fuel are generally smaller than USTs regulated under Subtitle I. The size distribution of nonresidential heating oil tank systems in California and Maine, however, is similar to that of USTs regulated under Subtitle I (Exhibit 2-9).

2.3.5 Contents

Exempt motor fuel tank systems most commonly contain gasoline or diesel fuel. Exempt residential and farm heating tank systems generally contain fuel oil Nos. 1 or 2, although some of the large residential facilities, particularly large multiple-family dwellings, use fuel oil Nos. 4, 5, or 6. (For purposes of this report, we have combined information regarding kerosene and fuel oil No. 1, as appropriate, because of the similar specifications of these products.) Exempt nonresidential heating oil tank systems contain a variety of heating oils, from fuel oil No. 1 to No. 6. The particular heating oil stored in tanks is determined by the type of heating equipment present at each facility. Fuel oil No. 2 is used most prevalently and is consumed in facilities of all sizes. In contrast, the use of residual fuels, such as fuel oils Nos. 5 and 6, is usually limited to large facilities (e.g., schools, shopping centers, or manufacturing plants), because burning these fuels requires special equipment that is generally cost effective only in very large facilities.

2.4 CURRENT MANAGEMENT PRACTICES

Information was gathered from interviews with state and local government officials and UST industry organizations to provide an overview of the leak prevention and detection methods currently practiced by exempt tank system owners and operators. Leak prevention and detection methods are less frequently practiced at exempt tank systems than at regulated USTs.

EXHIBIT 2-9

COMPARISON OF CAPACITY FOR EXEMPT TANK SYSTEMS AND REGULATED USTs

(Percent of Registered Tank Systems)

Tank Capacity (gallons)	Exempt Tank Systems: Heating Oil[a] Farm or Residential	Exempt Tank Systems: Heating Oil[a] Nonresidential	Exempt Tank Systems: Motor Fuel	Regulated USTs
<500	27	6	16	4
500-999	43	18	54	12
1000-1100	18	19	30	15
1101-4999	8	20	--	29
5000-9999	2	11	--	19
≥ 10,000	2	26	--	21
Total	100	100	100	100

Source: State UST Notification Data Bases from: California State Water Resources Control Board, Dec. 1986; Maine Dept. of Environmental Protection, Dec. 1986; and Montana Dept. of Health and Environmental Science, March 1987.

[a] Data for heating oil tanks includes data only from California and Maine. Montana data base did not contain sufficient data on facility type to identify use sectors.

2.4.1 Leak Prevention

Government officials from Connecticut, Kansas, Maine, Massachusetts, Minnesota, and North Carolina expressed the opinion that over 95 percent of exempt tank systems are made of bare steel and lack any protection against corrosion. Analyses of the notification data bases of Maine, Montana, and California (Section 2.3.2) confirm these findings. Furthermore, farm and residential tank systems are less likely to be made of noncorrodible materials or have cathodic protection than are nonresidential tank systems or USTs regulated under Subtitle I. According to representatives of the Steel Tank Institute, exempt farm and residential tank system owners are more likely to have lower quality tanks compared to other exempt tank system owners (STI 1986). Smaller tanks are more likely to be made with thinner steel, which may corrode faster than larger tanks. Furthermore, leak prevention measures are more likely to be used in the nonresidential heating fuel sectors than the farm and residential sectors (see the state notification data bases for California, Maine, and Montana).

Poor quality installation of tank systems and their piping was cited as another significant source of exempt tank system failures by UST officials from Connecticut, Kansas, and Maine. A group of Petroleum Equipment Institute members and installers noted that many installers are not using appropriate equipment or materials (USEPA 1987). Kansas officials report that farmers often have access to the heavy equipment needed to install an underground tank system and may incorrectly install their own systems. These installations often use native soils as backfill materials, a practice that increases the rate of exterior tank corrosion. Some farmers use USTs discarded by regulated UST owners, and this recycling of tanks occurs without proper inspection or tightness testing (KDHE 1986). Maine and Connecticut officials reported finding 275-gallon tanks installed underground (ICF 1988b). These tanks, which are not designed for underground use, have thin walls and are vulnerable to corrosion.

2.4.2 Leak Detection

Discussions with government officials indicate that exempt tank system owners and operators generally do not have effective release detection equipment and do not employ adequate operating practices (ICF 1988b). Except for areas covered by specific state or local regulations, exempt tank system owners are less likely to employ leak detection equipment or practices than owners of regulated USTs. Nonresidential tank systems are more likely to have leak detection equipment than residential or farm tank systems. Residential tank systems serving multiple-family complexes, however, may more closely resemble nonresidential USTs than single-family residential tank systems. Some nonresidential facilities with monitoring equipment for their regulated USTs may also monitor their exempt tank systems. Many owners of larger commercial or manufacturing tank systems storing fuel oil Nos. 4 or 6 employ operating engineers to monitor the tank systems (Oil Heat Task Force 1987). Sensitivity to public scrutiny and liability concerns, particularly for facilities operated for-profit by moderate- to large-size corporations, may also encourage the use of leak detection equipment at these nonresidential sites. In contrast, Maryland officials expressed concern that schools and churches frequently lack the financial resources and technical training to properly operate and maintain their heating oil tank systems (ICF 1988c).

Exempt farm and residential tank systems owners generally employ minimal, if any, leak detection. Few owners of exempt residential and farm tank systems practice inventory control measures using gauges or dip sticks; however, the Petroleum Marketers Association of America (PMAA) stated that water leaking into a perforated heating oil tank fouls the burner, indicates a leak, and reduces the need for leak detection measures (PMAA 1987). Water will enter a tank only if the tank is situated in the water table. In addition to the effect of water, PMAA stated that heating oil tank systems do have an effective inventory control program that is commonly run by petroleum distributors. These distributors are reported to employ a "degree day" monitoring program that uses past fuel consumption rates for each facility and recent temperatures to estimate fuel consumption. This information is used by distributors to indicate when more fuel oil needs to be delivered. Thus, representatives of the PMAA stated that significant releases from heating oil tanks would be detected when they occur.

Government officials from Maine, Minnesota, Rhode Island, Wisconsin, Barnstable County (MA), and Suffolk County (NY) reported that they do not believe that degree-day monitoring by the oil distributors is an effective leak detection monitoring practice (ICF 1988b). Connecticut officials stated that degree-day monitoring by distributors has not, to date, been useful for identifying unknown releases; however, if a release is known to have occurred, then such information can be helpful in identifying a potential source of the release (ICF 1988b). Similarly, New York officials could not identify a single case (from either exempt tank systems or federally regulated USTs) in which inventory monitoring, by either the owner or a second party for either type of these tank systems, was the initial source of a release report (NYSDEC 1987a and 1987b). They did agree that inventory records can be useful in identifying the source of a known release. Even if degree-day monitoring is an effective means of leak detection, not all heating oil tank systems would be monitored by this system. Not all distributors employ such a system, and, for those that do, only those heating oil tank owners who commit to purchasing heating oil under a "keep full" program from a single distributor would be effectively monitored.

2.5 SUMMARY DESCRIPTION OF EXEMPT TANK SYSTEMS

- There are nearly twice as many exempt tank systems as regulated USTs.

- Exempt heating oil tank systems:

  - comprise 87 percent of exempt heating oil and motor fuel tank systems;

  - significantly outnumber regulated USTs (2.7 million versus 1.7 million tank systems);

- -- are comprised mostly (69 percent) of residential tank systems; and

- -- are similar to regulated USTs in age and material of construction.

- Exempt motor fuel tank systems:

  - -- comprise 13 percent of exempt heating oil and motor fuel tank systems;

  - -- are significantly outnumbered by regulated USTs (0.4 million versus 1.7 million tank systems); and

  - -- are similar in age and material of construction to regulated USTs.

- Exempt tank systems usually use suction pumps while regulated USTs most frequently use pressure pumps.

- Exempt nonresidential heating oil tank systems are similar in capacity to regulated USTs, but exempt residential and farm tank systems tend to be smaller and have thinner walls.

- Effective methods of leak detection and leak prevention are practiced less often at exempt tank systems than at regulated USTs.

3. EXTENT OF RELEASES FROM EXEMPT HEATING OIL AND MOTOR FUEL TANK SYSTEMS

Section 3 differs from Section 2 by looking closely at leaking exempt heating oil and motor fuel tank systems rather than the total population of exempt tank systems. This section describes available information about the extent of releases from federally exempt heating oil and motor fuel tank systems. Unfortunately, detailed and documented information on this subject is scarce; therefore, this section summarizes both documented and anecdotal information on such releases. This section also compares releases from exempt tank systems with releases from regulated USTs and discusses the potential for releases from exempt tank systems.

Section 3.1 describes the sources of information concerning tank releases. Section 3.2 summarizes documented releases, including the number, sources, and effects of reported releases. Section 3.3 presents additional information about releases collected from individual states, including a summary of case histories for selected exempt tank system release incidents. Section 3.4 compares releases from exempt tank system with releases from regulated USTs. Section 3.5 assesses the potential for releases from exempt tank systems based upon information presented in Sections 2 and 3.

3.1 SOURCES OF INFORMATION

The most comprehensive source of documented information on releases from exempt heating oil and motor fuel tank systems is EPA's "State and Local Release Incident Survey" (referred to as the National Data Base in this study). This data base provides information on reported releases from 1,978 exempt heating oil tank systems, 25 exempt motor fuel tank systems, and more than 10,000 regulated USTs. The National Data Base includes only those releases that were reported to state and local government agencies from 1970 through the early part of 1985. Because the data base was not compiled using statistically valid sampling techniques, our ability to use the data to make inferences on a national basis is limited.

To supplement the National Data Base, additional information was obtained through telephone inquiries to state and local government officials, an EPA-sponsored workshop with five states and two counties, and visits to two other states (New York and Maryland). Although few states were able to assemble comprehensive data, Maryland's Department of Environment provided an unusually well-documented source of information on releases from exempt heating oil and motor fuel tank systems. This information is used to provide a comparison with the National Data Base.

Additional information obtained from New York State's Spill Response Data Base and the interim findings of a tank corrosion study being conducted for EPA by the Suffolk County Department of Health Services in New York (Pim 1987 and 1988) is also used in the analysis to provide a comparison with the National Data Base. Additional information regarding these sources is presented in Appendix B.

3.2 DOCUMENTED RELEASES

This section summarizes documented information of releases from exempt heating oil and motor fuel tank systems. The discussion includes information about the number and geographic location of reported releases, characteristics of the tank systems involved in releases, and the documented effects of releases. Additional information about releases from exempt tank systems is presented in section 3.3.

3.2.1 Number of Releases

The National Data Base documents 2,003 releases from exempt tank systems (Exhibit 3-1). Reports of releases from regulated USTs are more common than reports of releases from exempt tank systems. The National Data Base includes approximately five times as many reported releases from regulated USTs as from exempt tank systems. Interviews with a number of state officials and detailed reviews of files in selected states suggest that the National Data Base probably underestimates the number of releases from exempt tank systems (ICF 1987; ICF 1988b; ICF 1988c). There may be more reported releases from regulated USTs because of the greater mobility and volatility of gasoline, the product stored most frequently in regulated USTs, compared with that of heating oils, the product stored most frequently in exempt tank systems. In addition, owners of regulated USTs may be more aware of possible leaks and have systems with greater leak detection capability.

The annual rate of reported releases from exempt tank systems increased substantially from 1970 to 1984 (Exhibit 3-2) and continues to increase. For example, the National Data Base includes only 425 reports of releases from exempt tank systems nationwide in 1984, compared with:

- 237 reported releases in Maine during 1986;
- 295 reported releases in Maryland over a 2-year period beginning late 1985 (Exhibit 3-3);[1] and
- Approximately 1,500 reported releases of heating oil from exempt tank systems in New York over a 2-year period beginning late 1985 (Exhibit 3-4).[2]

Thus, the number of reported releases in just these three states in 2 years exceeds the number of incidents reported for the entire nation over the previous 15 years.

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[1] Maryland officials reported an additional 694 incidents of failures of exempt tank systems, including tank testing failures; however, the extent that stored product had been released in these incidents had not been determined.

[2] An unknown portion of these incidents, believed to be small, may involve heating oil releases from USTs regulated under Subtitle I.

Exhibit 3-1

NUMBER OF REPORTED RELEASES FROM EXEMPT TANK SYSTEMS BY SECTOR

Product	Sector: Residential	Sector: Farm	Sector: Nonresidential[a]	Total number	Total (%)
Heating Oils:					
Fuel Oil #1	5	0	67	72	(4)
Fuel Oil #2	222	6	752	980	(49)
Fuel Oil #4	10	0	123	133	(7)
Fuel Oils #5 and #6	5	0	253	258	(13)
Unspecified	155	5	375	535	(27)
Motor Fuels	21	4	--[b]	25	(1)
TOTALS	418	15	1,570	2,003	(100)
(%)	(21)	(<1)	(79)	(100)	

Source: EPA State and Local Release Incident Survey.

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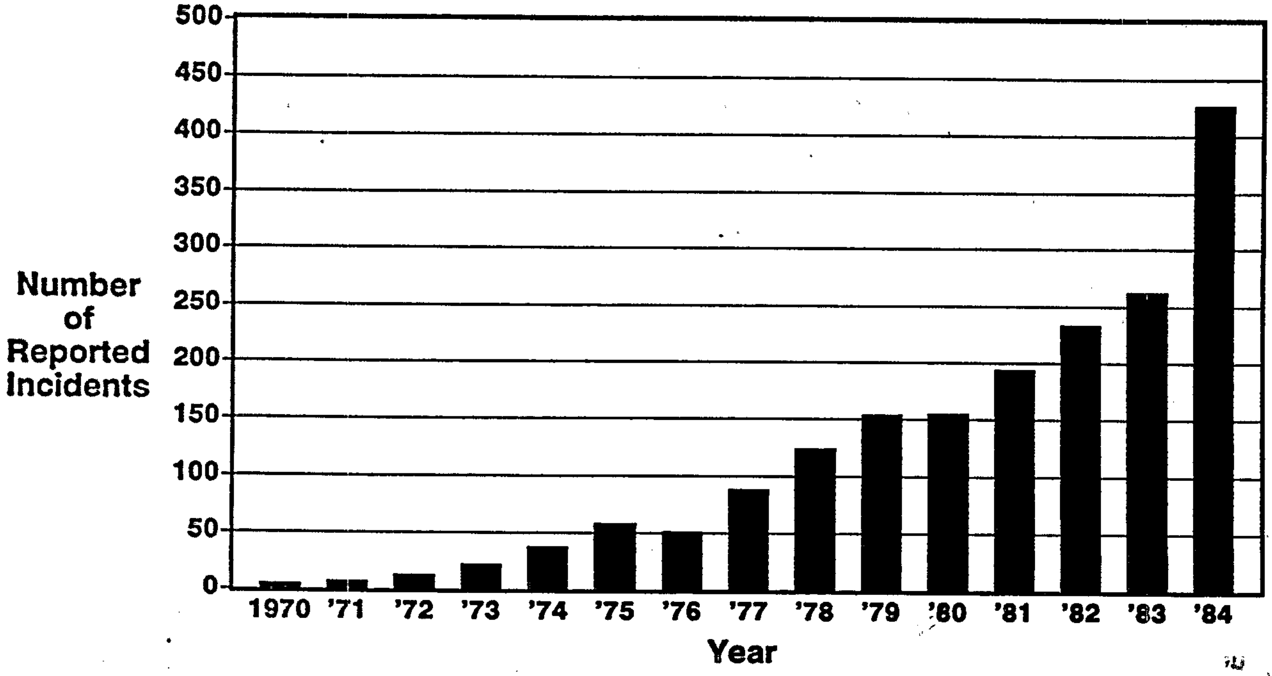
[a] This category includes commercial, institutional, government, and manufacturing facilities.

[b] These USTs are not exempt from Subtitle I regulation.

Exhibit 3–2

Number of Reported Releases from Exempt Heating Oil and Motor Fuel Tank Systems



Source: EPA State and Local Release Incident Survey.

Exhibit 3-3

REPORTS OF RELEASES FROM EXEMPT HEATING OIL AND MOTOR FUEL TANK SYSTEMS IN MARYLAND

(1985 TO 1987)

(Number of reported incidents)

Product	Sector: Residential	Sector: Farm	Sector: Nonresidential[a]	Sector: Unknown Sector	Total
Heating Oils:					
Fuel Oil #1	6	--	8	2	16
Fuel Oil #2	34	--	159	16	209
Fuel Oil #4	--	--	5	--	5
Fuel Oils #5 and #6	2	--	19	--	21
Unspecified	11	--	27	1	39
Motor Fuels:					
Gasoline	1	2	--[b]	2	5
TOTALS	54	2	218	21	295

Source: ICF 1988c.

[a] This category includes commercial, institutional, government, and manufacturing facilities.

[b] These USTs are not exempt from Subtitle I regulation.

Exhibit 3-4

REPORTS OF RELEASES FROM EXEMPT HEATING OIL TANK SYSTEMS IN NEW YORK

(1985 TO 1987)

(Number of reported incidents)

Product	Sector: Residential	Sector: Nonresidential	Estimated Total Underground[a]
Heating Oils:			
Fuel Oil #2	66	1192	1258
Fuel Oil #4	1	135	136
Fuel Oil #6	0	110	110
TOTALS	67	1437	1504

Source: ICF 1987.

[a] New York State Department of Environmental Conservation (NYSDEC) records reported releases of petroleum products from aboveground and underground tanks in the same data base without distinguishing the tank type for each incident. These estimates represent judgments of NYSDEC officials regarding the total number of reported incidents that were from exempt tank systems.

The increase in the number of reported releases is probably attributable to a combination of factors: (1) the recent increase in the awareness by tank owners and operators that their tanks may leak and possibly threaten public health and safety; (2) the development of new environmental protection programs and the increase in staffing of existing programs at the state and local level during the 1970s and 1980s (in fact, few programs kept track of such problems before 1970); and (3) the large number of underground heating oil tank systems installed during the 1950s and 1960s that have now reached the age at which tank failures are more likely to occur.

Releases reported in the National Data Base come from the following tank system sectors:

- About 79 percent from underground nonresidential tank systems (even though this sector comprises only 26 percent of the exempt tank system population);
- About 20 percent from underground residential tank systems (with single-family residences accounting for 83 percent of these releases);
- About 1 percent from underground residential and farm motor fuel tank systems (with single-family residences accounting for 80 percent of these releases);
- Less than 1 percent from underground farm heating oil tank systems.

There were only 11 releases from farm heating oil tank systems reported in the National Data Base (Exhibit 3-1), and Maryland officials did not report any releases from farm heating oil tank systems (ICF 1988c). However, reported releases from farm residences may not have been easily distinguished from residential releases in the available data.

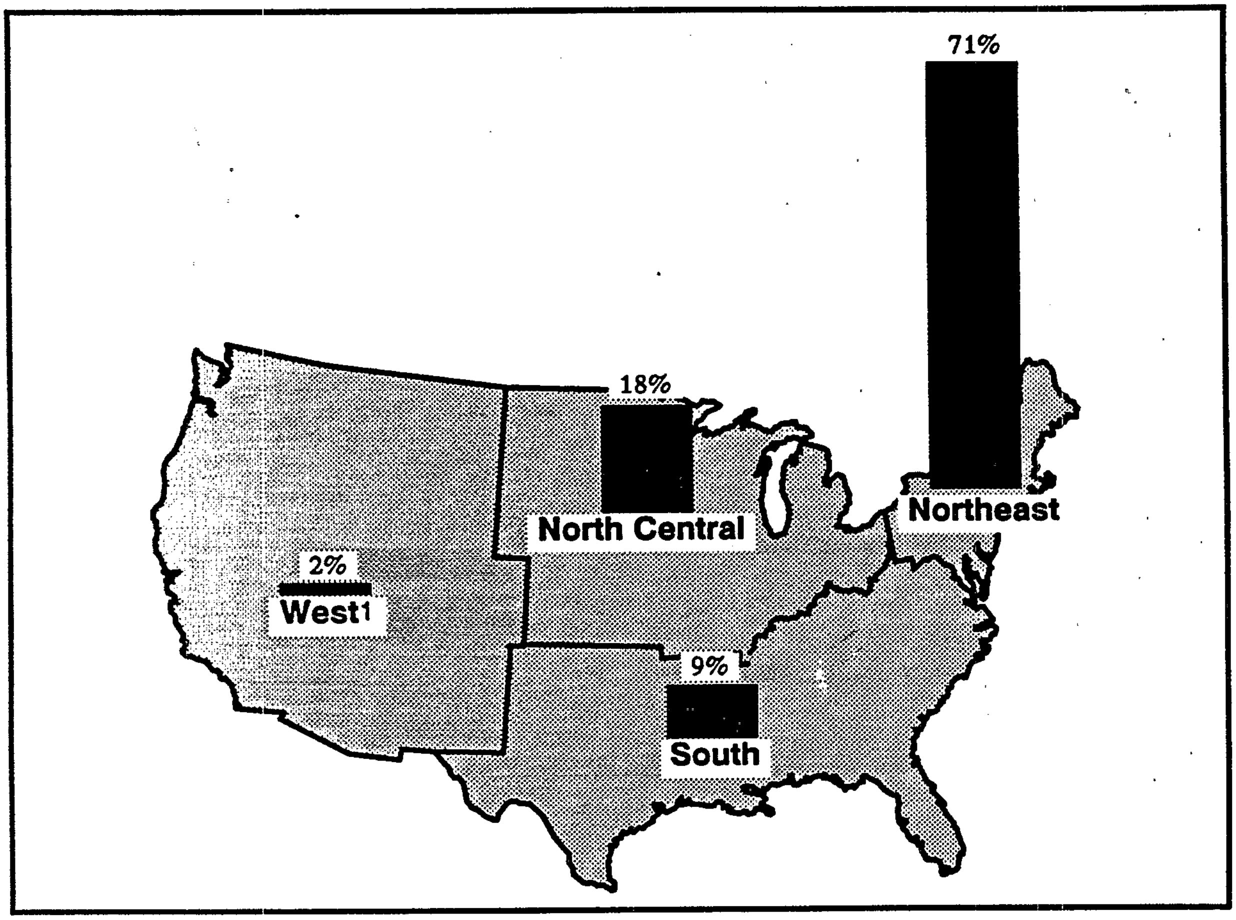
Some reasons for the disproportionate number of reported releases from exempt nonresidential tank systems are: (1) the larger quantities typically released from nonresidential systems, making detection of releases easier; (2) the more extensive state and local regulations for these tank systems than for federally exempt residential or farm tank systems; and (3) the greater familiarity of nonresidential owners and operators with leak detection practices and release reporting requirements.

3.2.2 Geographic Location of Reported Releases

Based on the National Data Base, 71 percent of reported releases of heating oil from exempt tank systems have occurred in the Northeast (Exhibit 3-5). This concentration of reported releases from exempt heating oil tank systems is consistent with their geographic distribution (Exhibit 2-2).

Exhibit 3–5

The Frequency of Reported Releases from Exempt Heating Oil Tank Systems by Geographic Region



Source: EPA State and Local Release Incident Survey (based on 1,905 incidents nationwide, 1970–1985).

[1] Totals for the West include Alaska and Hawaii.

3.2.3 Age of Leaking Exempt Tank Systems

The mean age of exempt tank systems with releases reported in the National Data Base varied little among the sectors: 20.0 years for residential tank systems, 20.2 years for nonresidential tank systems, and 15.5 for farm tank systems. Maryland data are consistent with these reported ages (ICF 1988c). More than 80 percent of the reported incidents in Maryland were from tank systems at least 16 years old.

3.2.4 Quantity of Product Released

For those incidents in the National Data Base with the quantity of release reported, most exempt heating oil tank systems incidents in both the residential and nonresidential sectors had releases of less than 500 gallons (Exhibit 3-6). In both sectors, releases were reported to be less than 100 gallons in about 40 percent of the incidents. Residential tank system releases were generally smaller than releases from nonresidential tank systems.

The accuracy of many of the documented estimates of the quantity released is generally unknown. New York State Department of Environmental Conservation representatives expressed a concern that the estimates of quantity released in New York were generally too low. New York State law requires the reporting of releases, but state officials felt there is a tendency for tank owners to minimize their description of the severity of a release during the initial reporting of a release (NYSDEC 1987b). Although the amount of product reported to be released is generally small, the amount of product actually released may be very large in some instances (see Section 3.3.2).

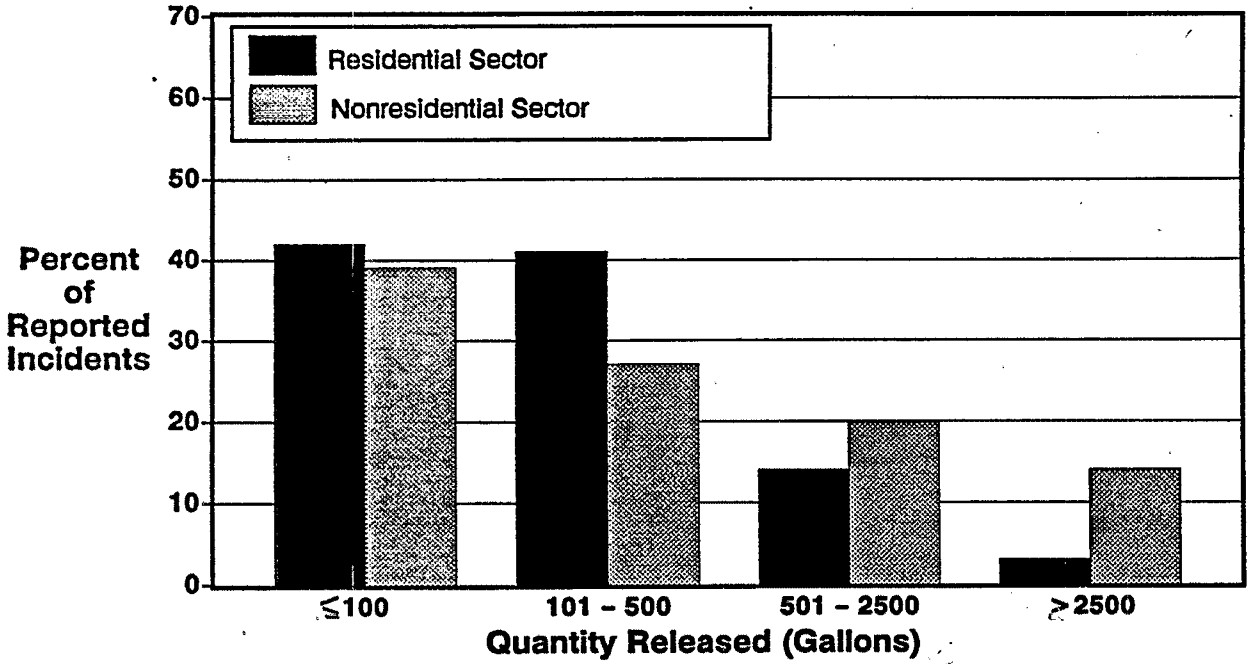
3.2.5 Products Released

More than two-thirds of the releases from exempt tank systems reported in the National Data Base for which the product is identified involve fuel oil No. 2. The proportion of the releases from residential facilities involving fuel oil No. 2 (92 percent) was higher than that at nonresidential facilities (63 percent). Fuel oil No. 2 was the product released in almost all single-family residential incidents, whereas multiple-family units more commonly reported releases of the heavier grade fuel oils. Fuel oil No. 2 was the only heating oil cited in releases from the farm sector where the product is specified. In contrast, nearly all releases of residual heating oils (fuel oil Nos. 4, 5, and 6) were from nonresidential tank systems.

Very little information is available concerning releases of motor fuels from exempt tank systems. The National Data Base contains only 25 reported incidents in 15 years. Of these 25 motor fuel releases, 20 originated from exempt tank systems serving single-family residences, 1 from a multiple-family building, and 4 from farms. Maryland reports 13 additional cases (less than 2 percent of the total) of release or tank test failure by exempt motor fuel tank systems over a 2-year period. These incidents also originated primarily from residential facilities.

Exhibit 3–6

Quantity of Product Released from Exempt Heating Oil Tank Systems



Source: EPA State and Local Release Incident Survey (based on 249 residential releases and 1,014 non-residential UST releases).

All but one of the motor fuel releases documented in the National Data Base involved gasoline (the remaining release involved diesel fuel). According to state and local government officials, the low frequency of releases reported from exempt motor fuel tank systems may result from owners and operators not inspecting their tank systems for releases. In addition, exempt motor fuel tank systems are commonly found in rural areas where the effects of a leaking tank system may not be noticed as quickly as releases in urban areas.

3.2.6 Location within Tank Systems where Releases Occur

Releases of heating oil from exempt tank systems originated at the tank itself in more than 50 percent of the incidents reported in the National Data Base (Exhibit 3-7). In nearly 30 percent of the incident reports, the fill pipe is indicated as the source of the release, suggesting an overfill. Other piping is cited as the source of the release in about 20 percent of the cases. Maryland data revealed that the fill pipe and the tank were the most common sources of releases, although fittings, supply lines, vent lines, and return lines were also commonly cited (ICF 1988c).

The 25 release incidents from exempt motor fuel tank systems reported in the National Data Base included a total of 66 sources of release, an average of more than two sources within each tank system. That is, multiple source releases were identified when the release incident was investigated. Tanks are the most commonly listed source of release for exempt motor fuel tank systems, foll wed by fill pipes and other parts of the piping.

Multiple s urces of releases were also reported for heating oil tank systems. Reports of multiple sources of releases at exempt tank systems may indicate that these tank systems are not being closely monitored and that tank system failures are not being detected early.

3.2.7 Environmental Damages and Corrective Actions Taken

The National Data Base yields very little information about specific environmental and health effects associated with releases from exempt tank systems. The lack of data, however, should not be interpreted as though the effects of these releases are minimal. Environmental effects may not necessarily be observed when release incident reports are completed, and effects may occur at points some distance from the original source of the release. Thus, any interpretation of the available data on environmental damages and health impacts must recognize the absence of systematic reporting and monitoring of the environmental and health effects of reported releases.

Heating Oil Tank Systems

Almost all of the 1,978 cases of heating oil releases from exempt tank systems recorded in the National Data Base indicate at least some degree of soil contamination (Exhibit 3-8). Most of the incidents also report contamination of ground water or surface water. Nine of the incidents include releases to private or municipal wells, and six incidents indicate impacts to human health.

Exhibit 3-7

LOCATION WITHIN EXEMPT HEATING OIL TANK SYSTEMS WHERE RELEASES OCCUR

(Percent of product releases for incidents that specified the location)

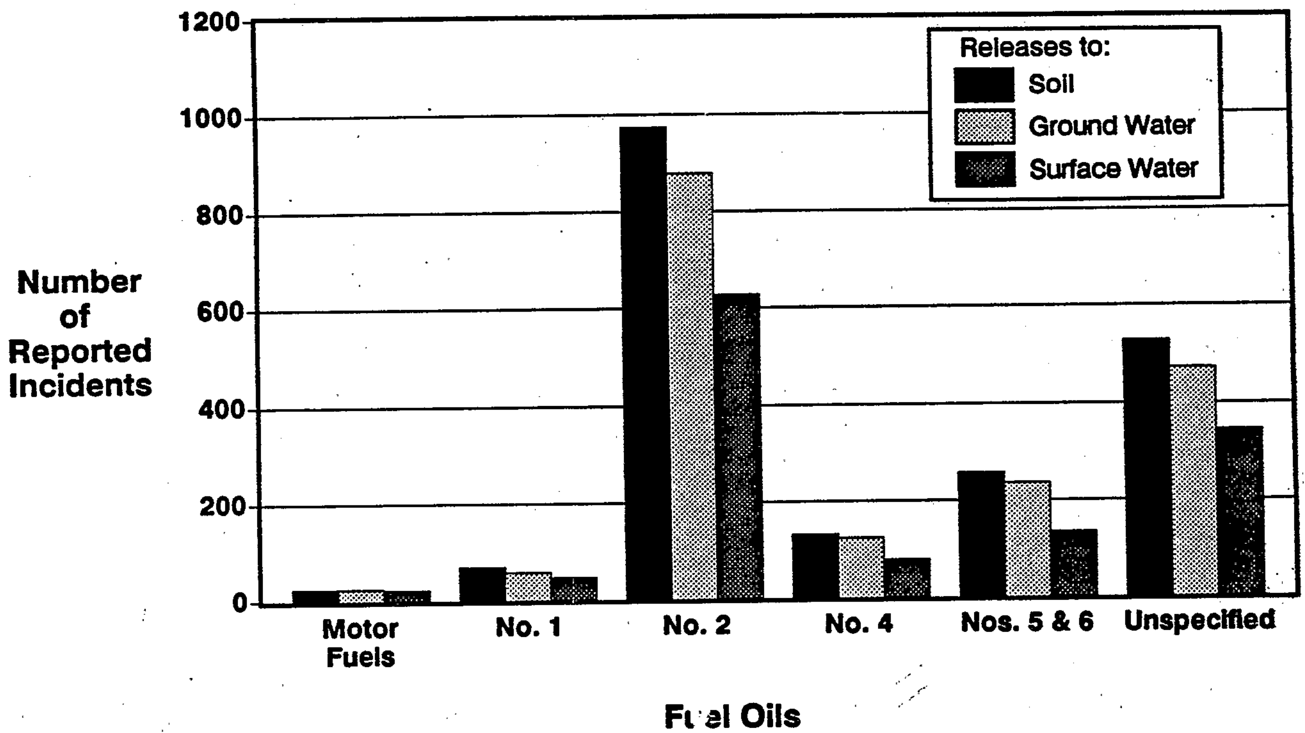
	Fuel Oil					Overall
Location	No. 1	No. 2	No. 4	No. 5 or 6	Unspecified	Frequency (Weighted Avg.)
Tank	66	50	33	35	63	51
Fill Pipe	13	28	40	46	19	28
Piping	16	21	24	17	17	20
Other	5	1	3	2	1	1
TOTALS	100	100	100	100	100	100
Number of Responses	63	835	120	220	431	1,669

Source: EPA State and Local Release Incident Survey (based on 1,669 responses[a]).

[a] A response refers to an individual citation regarding the location of a release. More than one location is commonly indicated for any given release incident.

Exhibit 3-8

Environmental Damages Reported from Exempt Tank System Releases



Source: EPA State and Local Release Incident Survey.

In Maryland, all of the 295 known release incidents indicate at least some degree of soil contamination. In addition, there are 26 cases of ground-water contamination, and three cases of surface-water contamination (ICF 1988c). These reports, however, probably understate the true extent of the problem, because most of these incidents were taken from summaries of initial release reports made before the extent of damage had been fully investigated.

A general pattern can be seen in the relative probabilities that various environmental media will be affected by releases of heating oil from exempt tank systems. Regardless of whether all cases are aggregated or if they are examined by sector, soil contamination is most commonly cited, followed by contamination of ground water, surface water, and wells, in that order.

A broad range of corrective actions taken in response to releases from exempt tank systems is documented in the National Data Base. The most commonly cited corrective action is removal or replacement of the tank or piping, followed by the use of barrier techniques, and various unspecified methods of product recovery. Soil excavation and use of absorbent materials were commonly reported. Although soil excavation and barrier techniques appear to be more common with the residual fuel oils (Nos. 4, 5, & 6) compared with the middle distillates (fuel oil Nos. 1 & 2), the differences are not great (Exhibit 3-9). In general, however, advanced methods, such as steam stripping and chemical techniques, are reported infrequently.

Motor Fuel Tank Systems

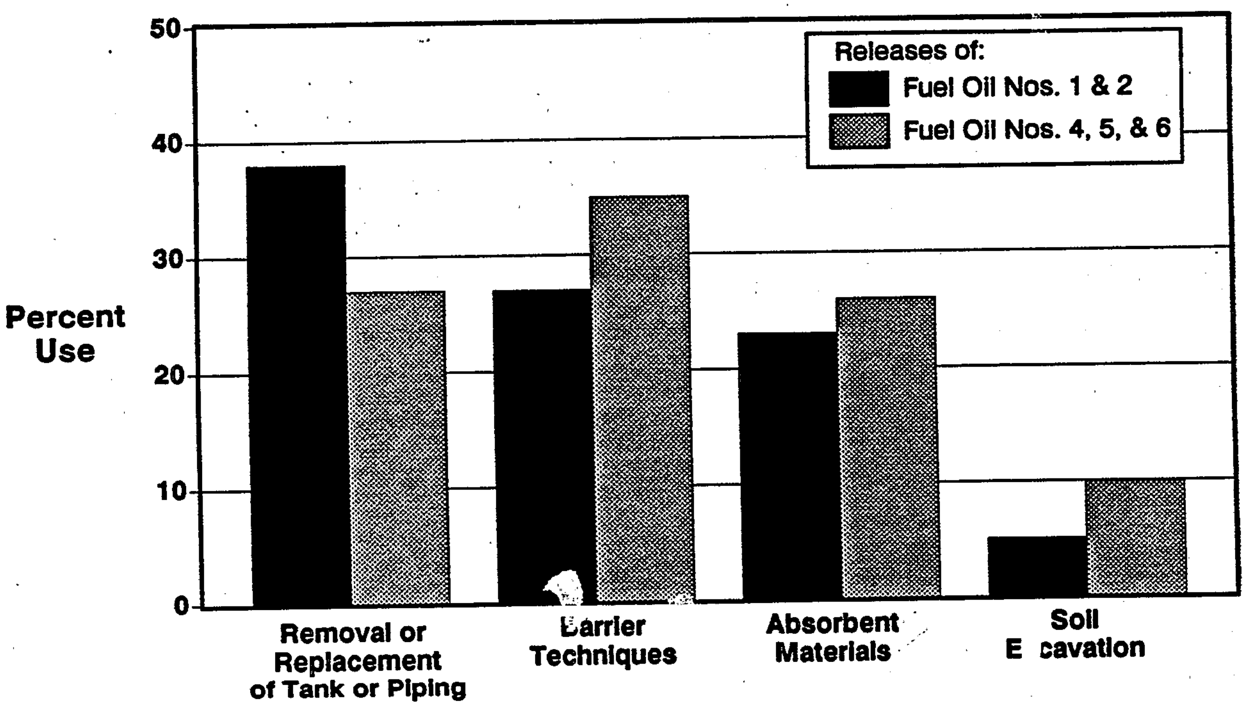
All 25 of the releases from exempt motor fuel tank systems recorded in the National Data Base indicated both soil and ground-water contamination. Twenty-three releases also reported contamination of surface water. Maryland reported 13 failures of exempt motor fuel tank systems in a 2-year period; five were known to have released stored product to the soil and one resulted in the contamination of ground water.

3.3 ADDITIONAL INFORMATION ON RELEASES

Much useful information on releases from exempt tank systems can be obtained from individuals who have experience with releases from exempt tank systems, but may lack quantitative data, or who have data on the condition of tank systems as they are removed from the ground rather than data on releases. Such informational sources can provide anecdotal or qualitative data that helps document the extent of releases from exempt tank systems. This information includes illustrative cases of releases, as well as both quantitative data and opinions of experts on the extent of releases, their causes, and the need to regulate exempt tank systems. Section 3.3.1 summarizes the interim findings of a study on tank corrosion. Section 3.3.2 presents the findings, comments, and recommendations from meetings with selected government officials. Section 3.3.3 qualitatively summarizes a few case histories of releases from exempt tank systems.

Exhibit 3-9

Frequency of Use of Selected Corrective Action Techniques
(Percent of Corrective Actions Reported)



Source: EPA State and Local Release Incident Survey (based on 440 responses for Fuel Oil Nos. 1 & 2 and 143 responses for Fuel Oil Nos. 4, 5, & 6).

3.3.1 Interim Results from a Tank Corrosion Study in Suffolk County, New York

A study of tank corrosion, being conducted for EPA by the Suffolk County Department of Health Services in New York, has revealed some new information about underground petroleum tanks that have been removed from service and taken out of the ground. Interim results of the study (through February 1988) are available for 317 tanks removed from the ground over the previous one year period. According to the most recent interim report (Pim 1988), 89 of the 317 tanks examined qualified as exempt tanks. Of the 89 exempt tanks, 31 (35 percent) had perforations and several tanks had multiple holes (e.g., one tank had 31 holes, another had 29 holes, and a third had 16 holes).

Although the sizes of the 31 exempt tanks with holes ranged from 275 gallons to 5,000 gallons, 26 tanks had a capacity of 1,000 gallons or more. All of the tanks with holes contained fuel oil No. 2, except for one 5,000-gallon tank that contained fuel oil No. 4. The ages of the exempt tanks with holes ranged from 6 to 55 years, although more than half (16 tanks) were either 26 or 27 years old. Twenty-three of the 31 tanks (74 percent) failed from exterior corrosion, four from interior and exterior corrosion, and two suffered weld failures. None failed from interior corrosion alone. Seven of the tanks with holes had been in direct contact with ground water.

The information from this continuing study is useful because, although no information on releases is provided, it reveals that exempt tanks seem to behave in a manner that is very similar to regulated steel tanks. For example, the percentage of exempt tanks with holes was essentially the same as the percentage of all tanks with holes (35 versus 34 percent, respectively; Pim 1987 and 1988).

3.3.2 Information from State UST Program Officials

EPA's meeting with state and local officials on December 2, 1987, provided additional information from selected state and county officials who have had experience with exempt tank systems. Exhibit 3-10 summarizes the information gathered at this meeting (ICF 1988b). Representatives from each state described several cases of release incidents involving exempt tank systems. The consensus of the representatives of the five state and two county programs was that:

- Exempt tank systems corrode and leak at approximately the same rate as regulated USTs;
- Releases from exempt tank systems contaminate ground water, surface water, and, in some cases, private and public wells;
- Contamination of ground water and wells is more common in areas with hydrogeological conditions that allow for rapid movement of product and is of greater concern in areas that rely heavily on ground water for drinking water;

Exhibit 3-10

SUMMARY OF MEETING WITH GOVERNMENT OFFICIALS

Source	Type of Release Data Available	Findings Relevant to Exempt Tank Systems
Barnstable County, Massachusetts	▪ Results of study on soil-vapor leak detection, testing.	▪ 4 illustrative incidents involving exempt tank systems ▪ One contaminated well.
Connecticut	▪ Petroleum product spill reports, including transfer accidents, overfills, and releases from underground tank systems.	▪ An estimated 1,600 total petroleum spills annually, most of which are fuel oil. Includes spills of all types.
Maine	▪ Total underground storage tank system releases, all petroleum types.	▪ 237 releases from heating fuel tank systems in 1986. ▪ 44 wells contaminated in 1986.
Minnesota	▪ Limited number of exempt tank system releases from files.	▪ Presented 9 illustrative incidents involving exempt tank systems: - Product loss ranging from 500 to 20,000 gallons; - 6 cases of ground-water contamination; - 2 cases of surface-water contamination; - 1 private well contamination; and - Transport of released product ranged from 13 to 80 feet vertically and 20 to 1,200 feet horizontally.
Rhode Island	▪ Limited number of exempt tank system release incidents from files.	▪ Presented 6 illustrative releases from exempt tank systems: - 4 cases of ground-water contamination - 2 private well contaminations
Suffolk County, New York	▪ Results, to date, of a study of underground tanks examined as they are removed.	▪ 95 exempt heating oil tank systems have been removed and inspected: - 28 had holes, of which 12 had leaked product - External corrosion was more frequent than internal corrosion.
Wisconsin	▪ Incidents involving leaking underground tank systems include all types of petroleum products.	▪ Estimated 15 to 23 current cases involving exempt tank systems. ▪ Presented 6 illustrative exempt tank system incidents: - 4 cases of ground-water contamination; and - 2 well contaminations.

Source: ICF 1988b.

- Releases of fuel oil No. 2 account for the majority of incidents resulting in ground-water contamination;
- More exempt tank system release incidents are reported from the nonresidential sector than the residential sector;
- Farm tank systems are a concern, although there is little data available to document the problem; and
- There is a definite need for some regulation of exempt tank systems.

Similar inquiries were made of officials from Maryland and New York during visits to collect data from UST programs that regulate federally exempt tank systems. Documentation of releases reported from Maryland is presented in Section 3.2. Based on estimates provided by New York State Department of Environmental Conservation (NYSDEC) officials, there were more than 1,500 reported release incidents involving underground heating oil tank systems in New York over a 2-year period (Exhibit 3-4). NYSDEC believes that more than 90 percent of the releases from exempt tank systems were from industrial facilities. Private dwellings account for about 5 percent of the total, virtually all involving fuel oil No. 2 (ICF 1987).

Officials from both Maryland and New York also indicated a need for exempt tank systems to be regulated. Some of these tanks are already being regulated in various states throughout the country (see discussion of current state regulations in section 5). Maryland officials find that requiring tank testing has identified many leaking exempt tank systems that would previously have gone unnoticed, and that almost one-fifth of the tank test failures revealed leakage rates greater than one gallon of product per hour (10 times the specified standard in the Subtitle I regulations).

3.3.3 Summaries of Selected Release Incidents

Most of the findings presented thus far regarding the extent of releases from exempt tank systems have been limited to information that is easily quantified. Exhibit 3-11 presents five brief case histories of exempt heating oil incidents. This exhibit is not intended to be a comprehensive or even representative list of documented release incidents for which descriptions are available; instead, Exhibit 3-11 represents incidents with either significant environmental effects or releases of large quantities of product over a long period of time.

Even though most releases are less than 500 gallons, conclusions that may be drawn from these case histories of release incidents are:

- Releases from exempt tank systems may continue for long periods of time without detection, during which time the amount of product released may become large; and
- Persistence of the released product in the environment can lead to protracted and expensive remedial action efforts.

Exhibit 3-11

SUMMARY OF SELECTED RELEASES FROM EXEMPT TANK SYSTEMS

Maryland. Department of Environment officials report that cleanup and containment action has continued for one exempt tank system release case for 14 years. The release was first detected when a nursing home switched from fuel oil No. 6 to fuel oil No. 2 and found that consumption greatly increased. The consumption increase was actually due to leakage; an estimated total of 300,000 gallons of product has been released into the soil from the tank system, 280,000 gallons of which has been recovered.

Massachusetts. The Barnstable County Health and Environmental Department (HED) has documented a large release of fuel oil No. 2 from a 275-gallon exempt heating oil tank system serving a private residence. The leak contaminated 15 cubic yards of soil, an on-site well, and a nearby pond. The extent of damage led HED officials to believe product was released over an extended period, possibly as long as 10 years. Corrective action is expected to cost $80,000 and will include removing the underground tank and contaminated soil and installing monitoring wells and a product recovery system.

Minnesota. In 1975 the Pollution Control Agency received an initial complaint of oil seepage into a basement, but the source of the release could not be determined at that time. Later, when the source (a creamery) was found, product recovery wells recovered 4,000 gallons of fuel oil No. 5, and the source -- a leaking 14,000-gallon tank (which had a hole) -- was removed. Twelve years later, oil seeping into nearby basements is still being reported, and the state has determined that the recovery efforts need to continue.

A second case, also requiring ongoing remedial action, involved a commercial tank system which released fuel oils No. 2 and No. 5 and caused extensive contamination of soil and ground water. Fuel oil No. 5 had not been used for several years before the leak was detected, indicating the release and ground-water contamination persisted over a long period of time. The state has conducted site remediation, but does not believe the problem has been fully resolved, even 10 years after the initial report of the spill.

Rhode Island. The Department of Environmental Management reports that a leak of fuel oil No. 2 from a tank serving a private residence has contaminated five private wells, requiring extension of the public water supply system. Total costs of remedial action for this case are estimated to be $200,000.

3.4 COMPARISON OF EXEMPT TANK SYSTEMS AND REGULATED USTs INVOLVED IN REPORTED RELEASES

To provide a context for evaluating the magnitude of the threat of releases from exempt tank systems, the following section compares data from the National Data Base for regulated USTs and exempt tank systems.

3.4.1 Differences

The National Data Base reveals several differences among releases reported from exempt tank systems and regulated USTs. Key differences identified include geographical distribution of release incidents, type of facility where the release occurred, and tank capacity.

Geographical Distribution of Release Incidents

Releases from exempt tank systems reported in the National Data Base occur primarily in the Northeast, an area characterized by high heating oil consumption. In contrast, regulated UST releases are more evenly distributed across the country.

Facility Type

Tank systems serving nonresidential facilities were involved in 78 percent of the reported releases from exempt tank systems. Releases from exempt nonresidential tank systems originate from a broad range of facilities, including commercial, manufacturing, residential, military, government, farm, and institutional facilities. In contrast, the National Data Base reveals that 63 percent of the reported releases from regulated USTs take place at retail gas stations (ICF 1988a). Thus, exempt tank systems involved in releases are more widely distributed among different sectors and operators than are regulated USTs.

Tank Capacity

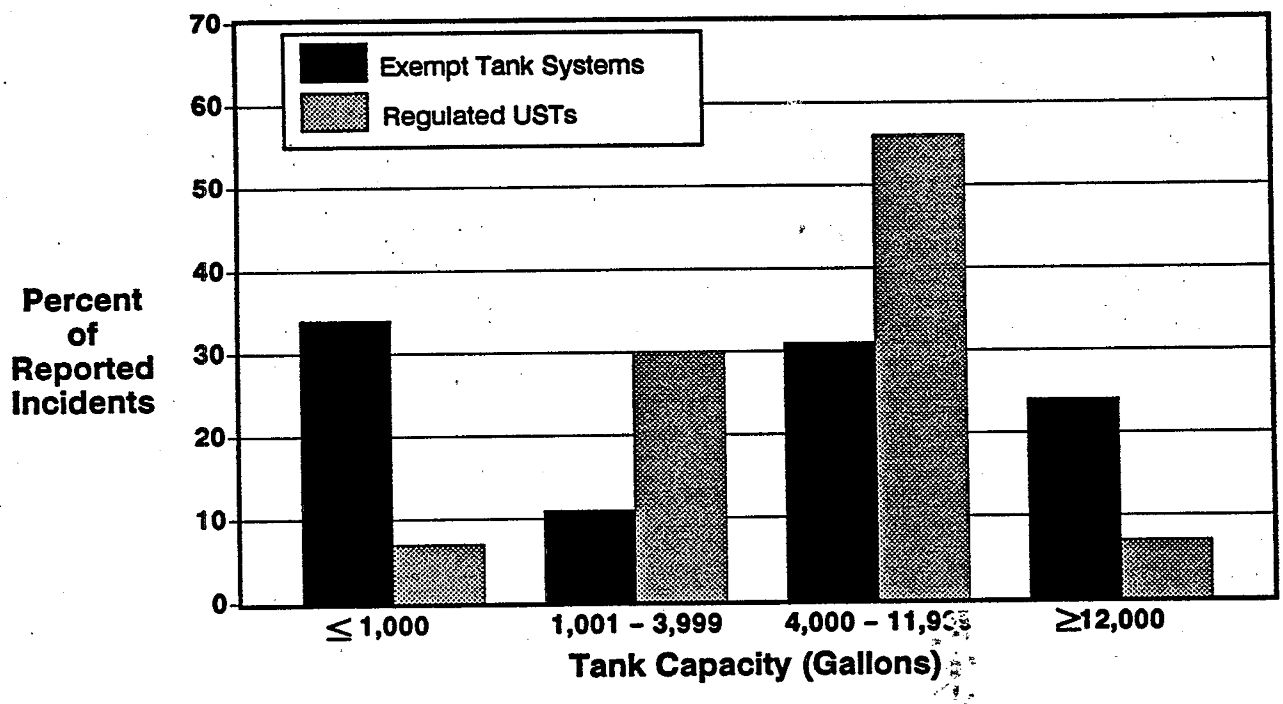
The average capacity of exempt tank systems reported to be leaking is smaller than the average capacity of regulated USTs reported to be leaking, but large tanks were more frequently a problem for exempt tank systems than regulated USTs. Exempt tank systems involved in releases may also be characterized by a wider range of tank capacities than regulated USTs reporting releases (Exhibit 3-12). There are significantly more exempt tank systems than regulated USTs with capacities less than 1,000 gallons.

3.4.2 Similarities

Similarities between releases reported from regulated USTs and exempt tank systems include the quantity of product released, age of tank system at release, material of construction, and cause of release.

Exhibit 3–12

Capacity of Exempt and Regulated USTs Reporting Releases



Source: EPA State and Local Release Incident Survey (based on 805 exempt and 3,532 regulated UST releases).

Quantity of Product Released

Based on incidents contained in the National Data Base, the exempt and regulated populations exhibit similar characteristics with respect to the quantity released. This is particularly true when the comparison is between nonresidential exempt tank systems and regulated USTs, because these two tank populations tend to have larger capacities and fuel releases than exempt residential and farm tank systems. Although the average capacity of exempt tank systems involved in releases is smaller than the average capacity of regulated USTs involved in releases, the average reported quantity released for each population is nearly the same (see Exhibit 3-13). For both populations, the most commonly reported quantity released is 100 gallons or less, with about a third of each population reporting release quantities in this range (these quantities include spills and overfills). For both exempt tank systems and regulated USTs, the number of releases decreases as the release quantity increases.

Age of Tank System at Release

The tank age data for reported releases from both regulated and exempt populations show similar trends (Exhibit 3-14). The mean age at the time of the reported release was 20 years for exempt tank systems and 18 years for regulated USTs.

Material of Construction

More than 80 percent of the tank systems reported to be leaking in both the exempt and regulated populations were constructed of steel, although the proportion of steel tanks was slightly higher for the exempt population.

Cause of Release

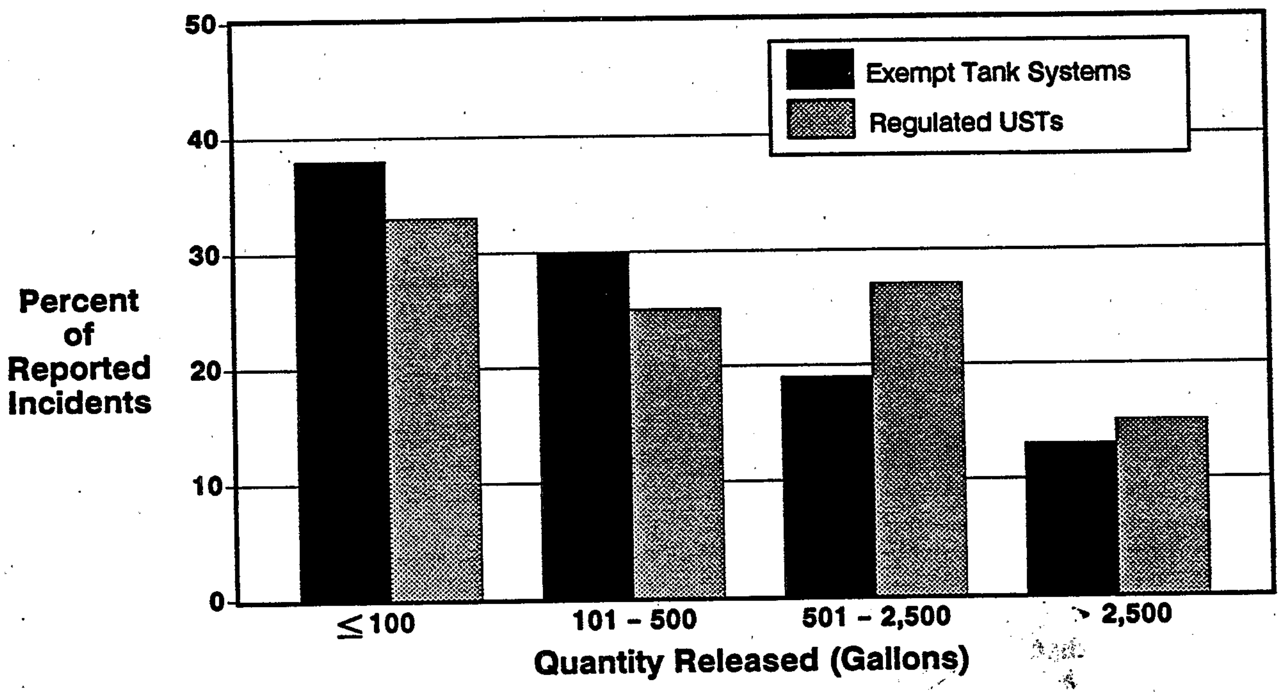
It is not possible to analyze quantitatively information regarding the cause of release in the National Data Base because of the ambiguous responses recorded in the survey. Survey respondents were allowed to select up to four causes for release on the survey form. Although the options listed were not mutually exclusive, structural failure, corrosion, spills, and overfills were the most commonly cited causes of releases for both regulated USTs and exempt tank systems. In a study examining underground tanks as they are removed from the ground, external corrosion, rather than internal corrosion, was the predominant cause of holes in steel tanks (Pim 1987 and 1988).

3.5 POTENTIAL FOR RELEASES

Limited documented information is available about releases from exempt tank systems. The National Data Base contains only information that has been reported to states and local agencies and may represent only a small fraction of actual releases from exempt tank systems. These types of tank systems usually are not equipped with release detection devices, receive little management attention, and generally do not have spill and overfill protection devices. Evaluating the potential for releases must, therefore, take into account the factors that affect the likelihood for failures to occur. This

Exhibit 3-13

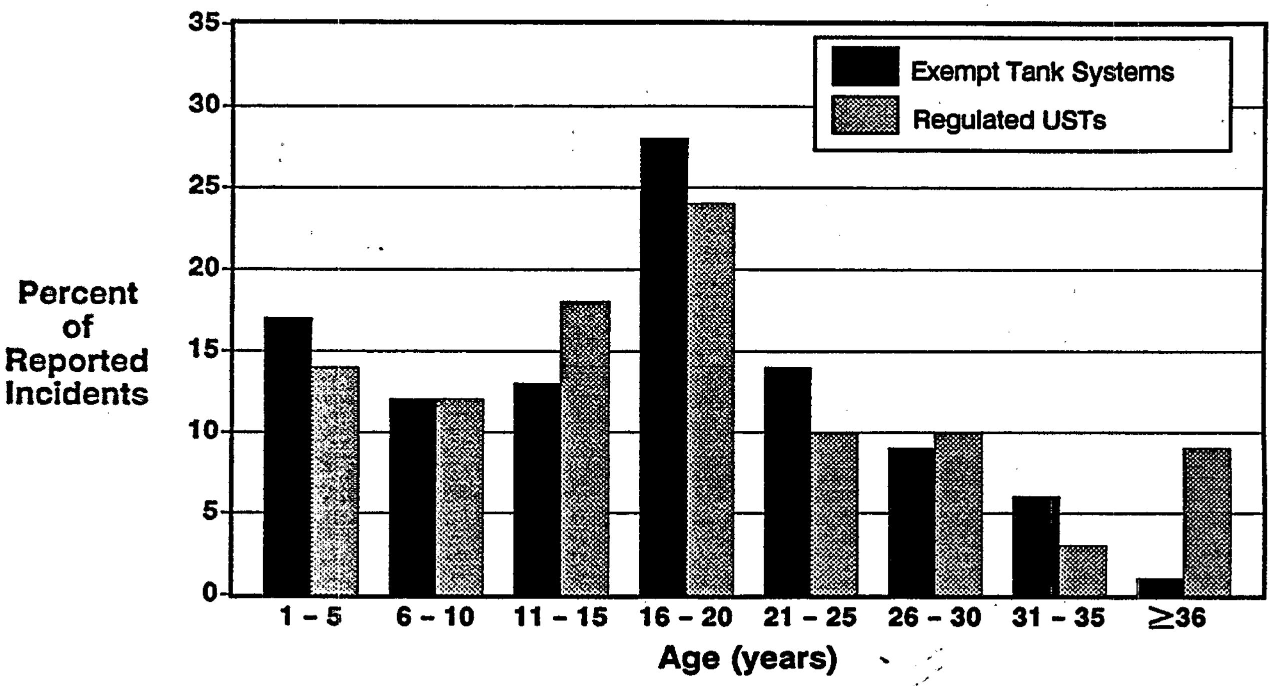
Quantity of Product Released from Exempt and Regulated USTs



Source: EPA State and Local Release Incident Survey (based on 1,189 exempt and 4,765 regulated UST releases).

Exhibit 3-14

Age of Exempt and Regulated USTs Reporting Releases



Source: EPA State and Local Release Incident Survey (based on 134 exempt and 1,356 regulated UST releases. Incidents reporting an age of less than one year are omitted).

section summarizes the potential for releases from exempt tank systems using a comparison with regulated USTs as a basis for the discussion.

3.5.1 Cause of Release

There appears to be no significant difference in the potential for releases from exempt tank systems versus regulated USTs based on material of construction. Both populations are constructed most often out of bare steel and are of similar ages. There also appears to be no major difference in the causes of releases reported from exempt tank systems and regulated USTs. In both cases, structural failure, corrosion, spills, and overfills are the most frequently cited causes of release. In addition, there is no evidence to suggest that the characteristics of heating oils or motor fuels significantly affect their potential for corrosion of the tank system, especially since external rather than internal corrosion appears to cause tank corrosion more frequently (Pim 1987 and 1988).

PMAA (1987) suggested that stray electrical currents increase the rate of external corrosion of a tank and that these forces are more prevalent at regulated UST facilities. Assuming this is true and ignoring the importance of site-specific conditions, factors such as these might decrease the rate of corrosion, but not the ultimate result (bare steel tanks would still corrode). Comparison of the age of exempt tank systems with that of regulated USTs that have released product fails to support the claim that exempt residential tank systems are significantly older when they corrode than are regulated USTs.

3.5.2 Quantity of Releases

Although the potential to release stored substances is believed to be similar between exempt tank systems and regulated USTs, it is difficult to ascertain whether the potential total amount released is greater for regulated USTs than for exempt tanks. The total amount of product released is a function of total amount stored, the rate of release, and the duration of the release. Determining the cumulative effects of these different factors is difficult.

The storage capacity of nonresidential exempt heating oil tank systems is similar to the storage capacity of regulated USTs; however, exempt residential and farm tank systems tend to be smaller. Thus, the maximum potential quantity released from a sudden catastrophic release is similar between exempt nonresidential heating oil tank systems and regulated USTs, but is less for exempt residential and farm tank systems than for regulated USTs.

The rate of release of stored product is expected to be slower from exempt heating oil tank systems than regulated USTs for two reasons. First, exempt tank systems typically store heating oils while regulated USTs more frequently store gasoline. Because of the higher viscosity of fuel oils than motor fuels (see Section 4), heating oils would typically drain more slowly from a tank system assuming other variables are the same. This is particularly true of some of the residual fuels (such as fuel oil Nos. 5 and 6), which may have to be heated in the tank in order to flow. Second, exempt tank systems typically use suction pumps to deliver the stored substance from the tank to the delivery point, but regulated USTs more frequently use pressure pumps. When a leak occurs in the piping, the most frequent location of reported releases in regulated USTs, the products stored in exempt tank systems are typically under negative pressure in the supply line and low positive pressure in the return line (which carries unused fuel from the burner back to the tank). In contrast, the products stored in regulated USTs are typically under much higher positive pressure. The viscosity and pressure differences significantly increase the rate of released product from the UST system for regulated USTs, compared with exempt tank systems.

Although differences in viscosity among stored products may affect the rate of release, the effect of viscosity on the quantity released is unknown. In one potential scenario, a slower release rate may mean less free product is released to the environment, because the problem is corrected before much stored product has been released. In contrast, it is conceivable that a slower release rate of a more viscous product could go undetected and consequently, a higher total volume could be released over a longer period of time. Documented data reveal that exempt tank systems are as capable as regulated USTs of generating large releases over protracted periods of time (see Exhibit 3-11).

The reported quantity of releases from both exempt tank systems and regulated USTs tends to be small -- more than two-thirds of reported releases are less than 500 gallons. Although releases from exempt residential tank systems tend to be smaller in quantity than releases from regulated USTs, these differences, in general, are not appreciable.

3.5.3 Number of Potential Releases

The number of potential releases is much higher for exempt tank systems than for regulated USTs because exempt tank systems are nearly twice as abundant as regulated USTs. (This discounts differences between these two groups regarding the likelihood of repeated releases from the same tank systems.) The residential sites represent nearly 60 percent of the potential sites for releases from exempt tank systems, exceeding the number of potential sites for releases from regulated USTs.

Although there are more potential sites for releases from exempt tank systems than regulated USTs, there are fewer reported releases from exempt tank systems. This discrepancy could be due to differences in the occurrence, potential, detection, and reporting of releases. Analyses of the likely factors affecting the initiation of a release suggest that even if the true occurrence of releases (and not just reported releases) has been less to date for exempt tank systems than for regulated USTs, the potential for release may be similar. Exempt tank systems may corrode more slowly than regulated USTs, but they still corrode and will eventually leak. Information regarding the fate and transport of released product, which affects the likelihood of detection, is presented in Section 4.

4. POTENTIAL IMPACTS ON HUMAN HEALTH AND THE ENVIRONMENT FROM PRODUCTS RELEASED FROM EXEMPT HEATING OIL AND MOTOR FUEL TANK SYSTEMS

All of the products stored in exempt heating oil and motor fuel tank systems contain noncarcinogenic substances that can cause adverse health effects. In addition, some of the products contain known or probable carcinogens. Releases of heating oil and motor fuels from exempt tank systems can adversely impact human health through contamination of air, soil, surface water, and, most significantly, ground water.

Most releases from exempt tank systems travel similar routes as releases from regulated USTs. Products from releases can saturate soils and dissolve in ground water. Volatile components of stored products can also vaporize and contaminate the air. The most likely route to human exposure of the water-soluble components of petroleum products in exempt tank systems is through drinking, bathing, and other direct contacts with contaminated water, or by breathing vaporized components while showering. Releases can also seep into basements, exposing humans directly to pools of released products, as well as to additional hazards of fire and explosion. Humans can also be exposed through contact with contaminated soil. This exposure can occur when fluctuations in the water table cause released petroleum products to rise to the surface and during construction operations and cleanup of a release.

Potential impacts to human health from releases of products stored in exempt tank systems were evaluated by:

- Identifying the physical properties and chemical constituents;
- Investigating the mechanisms by which the released products migrate after they are released; and
- Analyzing the hazard to human health and the environment posed by released products.

4.1 TOXICITIES OF PRODUCTS STORED IN EXEMPT TANK SYSTEMS

Exempt tank systems are used to store a variety of petroleum products, including gasoline and diesel fuel (motor fuels), and fuel oils Nos. 1, 2, 4, 5, and 6 (heating oils). With the exception of gasoline, stored in less than 13 percent of exempt tank systems, the toxicities of these fuels have not been well studied, and only limited information is available regarding the fuels as mixtures. Gasoline, which has been the subject of extensive study under EPA's RCRA Subtitle I regulatory program, is already classified as a probable human carcinogen (API 1983, USEPA 1985a, ICF 1988a). As a result, this discussion of the toxicities of products stored in exempt tank systems focuses primarily on heating oils, which account for most of petroleum products stored in exempt tank systems.

The exact compositions of heating oils vary widely depending on the source of the crude oil and the refining process used; standards for petroleum products are based on physical properties and not constituents. It is possible, however, to describe the health effects of some of the likely constituents of the fuels. Because concentrations fluctuate dramatically and many of the constituents of the fuels are unknown, the toxicity suggested by the components may not be the actual toxicity of the product.

Exhibit 4-1 summarizes the health effects of some of the constituents of gasoline and heating oils. Additional toxicity information and concentration data for the constituents can be found in Appendix C.

4.1.1 Middle Distillate Fuels: Diesel Fuel, Kerosene, and Fuel Oil Nos. 1 and 2

Some members of the middle distillate family (fuel oil No. 2 and diesel fuel) have been shown to be weak to moderate carcinogens when painted on the skin of laboratory animals (USEPA 1985c). In addition, these fuels contain other substances that may cause kidney, liver, and eye damage in humans. In humans, toxic kidney effects were reported in one adult who used diesel fuel to clean his hands and arms for several weeks, and in another who used diesel fuel as a shampoo (Crisp et al. 1979; Barrientos et al. 1977).

The middle distillate fuels contain compounds known as polynuclear aromatic hydrocarbons (PAHs), which may be a significant health concern. One of the PAHs found in the middle distillates, naphthalene, causes tremors, vomiting, and eye damage (IARC 1983; 1984; USEPA 1982). Two others (benzo(a)anthracene and benzo(a)pyrene) have been detected at very low levels in several samples of fuel oil No. 2 and are probable human carcinogens (Tomkins and Griest 1987; Pancirov and Brown 1975; USEPA 1986b).

In addition to PAHs, the middle distillates contain cresols and phenols. These compounds are toxic to the liver and kidneys (USEPA 1985d). Three of the toxic constituents of gasoline, namely toluene, xylenes, and ethylbenzene, are also found in the middle distillates; however, they are present in these fuels in much lower concentrations. Other constituents found in the middle distillates are also known to cause adverse effects on human health (Appendix C).

4.1.2 Residual Fuels: Fuel Oil Nos. 4, 5, and 6

The carcinogenicity of the residual fuels has not been well studied. There are, however, several reports indicating that at least two of the blending stocks used in their production are carcinogenic in mice (USEPA 1985b; API 1985). In fact, one of them (catalytically cracked clarified oil) is recognized as one of the most carcinogenic materials in the petroleum refinery (USEPA 1985b; API 1985).

The known constituents of most concern in the residual fuels are the PAHs. These compounds are present in higher concentrations in the residual fuels than in gasoline or the middle distillates. The two PAHs that are probable human carcinogens and have been found in the middle distillates in

Exhibit 4-1

ADVERSE HEALTH EFFECTS ASSOCIATED WITH EXPOSURES TO SOME CONSTITUENTS OF MOTOR FUELS AND HEATING OILS

FUEL TYPE	CONSTITUENT	POTENTIAL HEALTH EFFECTS
Gasoline	Benzene	Human carcinogen
Middle Distillates	Polynuclear aromatic hydrocarbons (PAHs):	
(Kerosene, diesel fuel, fuel oil Nos. 1 and 2, and some blends of No. 4)	naphthalene	Causes malaise, tremors, vomiting, and eye damage
	benzo(a)anthracene	Probable human carcinogen
	benzo(a)pyrene	Probable human carcinogen
	Cresols and phenols	Irritates skin, mucous membranes, and eyes May be cancer promoters
Residual Fuels	PAHs:	
(Fuel oil Nos. 5 and 6, and most blends of No. 4)	benzo(a)anthracene	Probable human carcinogen
	benzo(a)pyrene	Probable human carcinogen
	chrysene	May be a carcinogen
	Catalytically cracked clarified oil	Potent carcinogen in animals

Source: Based on literature review performed by ICF Incorporated.

small amounts have been found in higher concentrations in fuel oil No. 6 and are probably present in the other residual fuels. In addition, a third PAH, chrysene, may be carcinogenic in animals (IARC 1983). Because the residual fuels tend to have relatively high concentrations of these compounds, PAHs other than the ones mentioned here may also be present but have not been reported. Arsenic, a human carcinogen, has been detected at low concentrations in samples of fuel oil Nos. 4 and 6 (GCA 1983; USEPA 1986b). As with gasoline and the middle distillates, the constituents discussed above are probably not the only toxic constituents present in the residual fuels.

4.2 FATE AND TRANSPORT OF RELEASED PRODUCTS

The physical properties of motor fuels and heating oils affect how these products move in the ground after being released from an underground storage tank system. The specific properties and transport mechanisms are described below for a typical release as it migrates downward from the tank, through the unsaturated zone, until it reaches the water table and migrates in the general direction of ground-water flow (Exhibit 4-2).

4.2.1 Transport Through the Unsaturated Zone

Transport of product in the unsaturated zone is characterized by a gravity-driven downward flow, with some lateral spreading of the plume depending on differences in soil permeability (i.e., number and size of pores). A primary factor affecting this downward migration is the kinematic viscosity of the product, or its resistance to flow. A product with a relatively low kinematic viscosity, such as gasoline, kerosene, or fuel oil No. 1 is likely to move through the unsaturated zone much more quickly than a product with a relatively high kinematic viscosity, such as fuel oil No. 5 or No. 6.

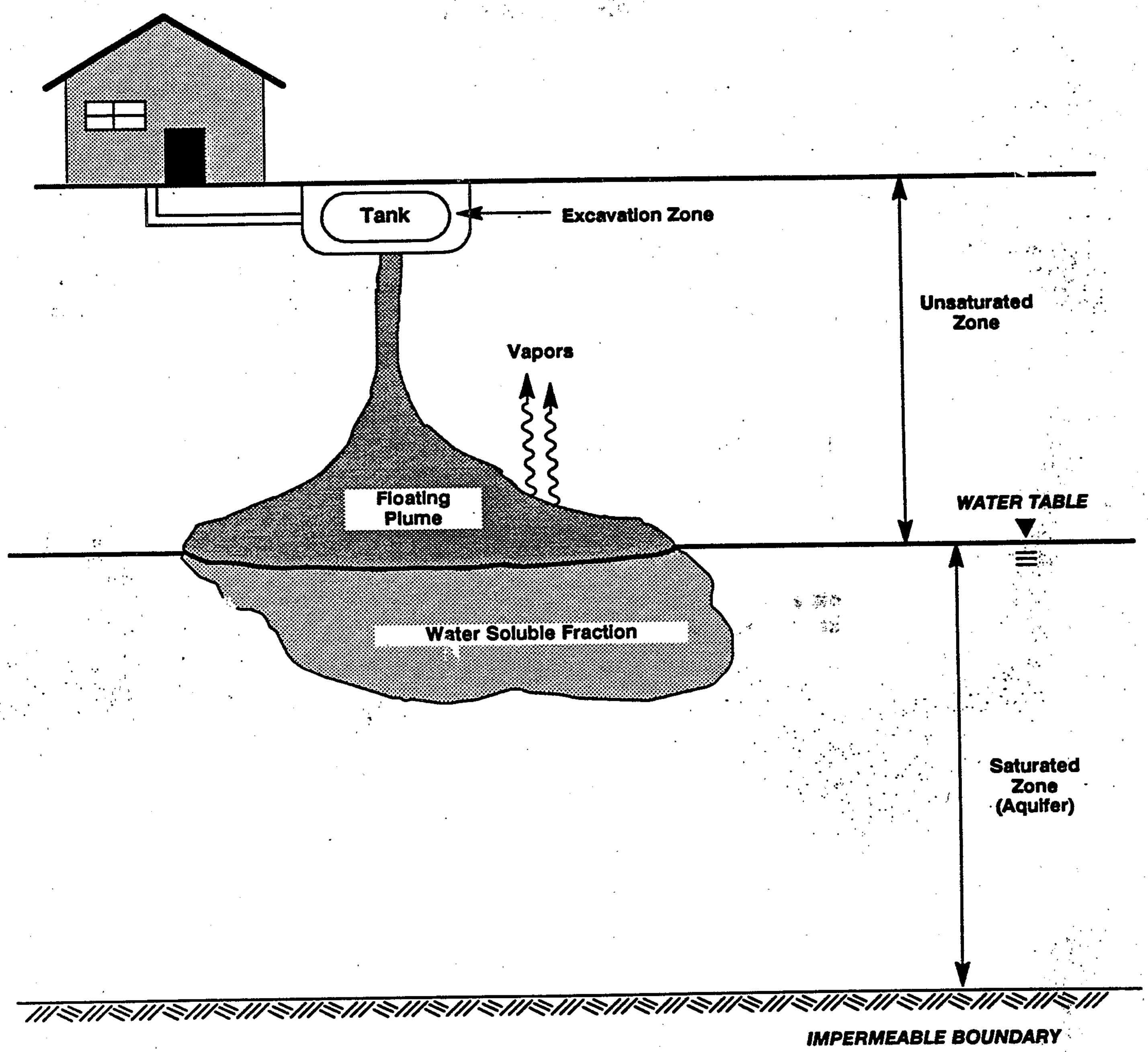
Some or all of the released product may cling to the soil or rock particles during the downward migration of released product. This process, known as adsorption, is particularly extensive with the heavier fuel oils. Even within a specific product, however, the lighter constituents tend to move farther and faster than the heavier components. Heavier fuels also tend to be be retained in the subsurface materials and trapped in the pore spaces rather than being dispersed and diluted. Thus, the lighter fuels are likely to contaminate a larger area than the heavier fuels. On the other hand, the tendency of the heavy fuels to be retained may result in greater concentrations of contamination in an area.

4.2.2 Transport on Surface of the Water Table

As released product travels downward through the unsaturated zone, it passes through areas of increasing water saturation. Eventually, it reaches the water table, which marks the boundary between the saturated and unsaturated zones (Exhibit 4-2). Because motor fuels and most heating oils are less dense than water, they tend to spread out on top of the water table. As increasing amounts of the release reach the water table, the flow spreads out, forming a free product plume with the general shape of a pancake (CDM 1986). An example that illustrates the spread of a released product is an

Exhibit 4–2

Schematic of Subsurface Environment



Source: ICF Incorporated analysis.

incident in Saint Paul, Minnesota, that involved a release of 4,000 gallons of fuel oil No. 4. Soil borings indicated a plume floating on the water table ranging from 60 to 100 feet in diameter and from 13 to 20 feet deep (ICF 1988b).

Fluctuations in the water table may force previously adsorbed constituents to become mobile again and become part of a migrating plume. Thus, motor fuels and fuel oils that are retained in the soil and rock matrix will be a continuing source of contamination long after initial corrective actions are taken (Kemblowski et al. 1987, Baradat et al. 1981). In another Minnesota release incident, changes in the ground-water table led to the discovery of additional contamination in the subsurface soil long after remediation was thought to have removed the contamination (ICF 1988b).

4.2.3 Transport in the Saturated Zone

In addition to the plume of contaminants that floats on the surface of the water table, a portion of the plume (the water soluble fraction shown in Exhibit 4-2) will mix with the ground water and move along the main direction of ground-water flow. In general, gasoline and the lighter heating oils contain greater concentrations of soluble constituents than the heavier heating oils and are, therefore, likely to be transported farther in the saturated zone. Fuel oil Nos. 5 and 6 tend to have few constituents that are water soluble (USEPA 1985b).

4.2.4 Transport of Vapors

Of the motor fuels and heating oils studied in this report, only the lighter products, such as gasoline, kerosene, and fuel oil No.1, have constituents that are likely to volatilize in substantial amounts. The heavier products (fuel oils Nos. 4, 5, and 6) generally do not have volatile components that generate vapors easily transported in the soil.

4.2.5 Fate Processes

Several mechanisms will affect how long petroleum products will remain in the subsurface environment and influence the hazard posed by a release. Although dispersion and dilution do not destroy the released constituents, these processes may reduce released concentrations to undetectable levels. Adsorption to subsurface materials and retention in the pore spaces, however, tend to oppose these processes and may trap the released product indefinitely. Constituents may also be transferred to another medium, such as volatilization to air or release to surface water. In addition, biodegradation (breakdown by living organisms) may also help reduce contaminant levels, particularly for the aromatic fraction of the fuels. The heavier fuel oils are not as biodegradable because of their large molecular sizes and low solubilities.

4.3 SUMMARY OF POTENTIAL RISKS TO HUMAN HEALTH AND THE ENVIRONMENT

Many of the petroleum products stored in exempt heating oil and motor fuel tank systems are known to contain probable human carcinogens and other compounds harmful to human health; however, the exact concentrations of the hazardous substances present are unknown. Although the exact level of risk posed by releases of these products is impossible to assess, relative risks can be assigned based on the toxicity of the product and its constituents, and the likelihood of the products to contaminate soil, air, surface water, and ground water.

- Contaminated ground water is the most likely route to human exposure of products released from exempt tank systems. Consumption of low levels of contaminants in ground water may occur for long periods of time and probably represents the more significant threat to human health. Higher levels of contamination are less of a problem because people are less likely to drink water that has a bad taste or smell.

- Gasoline is the most studied fuel stored in exempt tank systems. Gasoline is likely to travel faster in the soil than other products stored in exempt tank systems and is a probable human carcinogen.

- Of the heating oils, the middle distillates, such as fuel oil No. 2, probably pose the greatest threat to human health. These products are stored more frequently in exempt tank systems than are motor or residual fuels and, although slightly less mobile than gasoline, they are still likely to contaminate ground water. In addition, low levels of probable human carcinogens have been detected in fuel oil No. 2. The middle distillates also contain other substances known to have adverse health effects.

- Residual fuels, such as fuel oil No. 6, probably pose a smaller threat to human health than the middle distillates, but this threat may still be significant. Even though fuel oil No. 6 contains relatively high levels of probable cancer-causing substances, it can be so viscous (thick) that it is unlikely to reach ground water in large quantities. However, under certain conditions, such as incidents when fuel oil No. 6 was released near a sewer line or into fractured bedrock, large amounts of contamination have occurred. Furthermore, although residual fuels are not as mobile as the middle distillates, they are difficult to clean up after a release and are likely to persist in the environment longer than other fuels.

5. STATE AND LOCAL REGULATION OF EXEMPT HEATING OIL AND MOTOR FUEL TANK SYSTEMS

Many states and localities have already addressed the regulation of exempt heating oil and motor fuel tank systems. This section reviews the status of state and local regulatory UST programs to determine if federally exempt tank systems are regulated under their statutes. Unless specifically qualified in this section, the terms "exempt" and "regulated" refer to federal regulation under Subtitle I.

5.1 STATE REGULATIONS

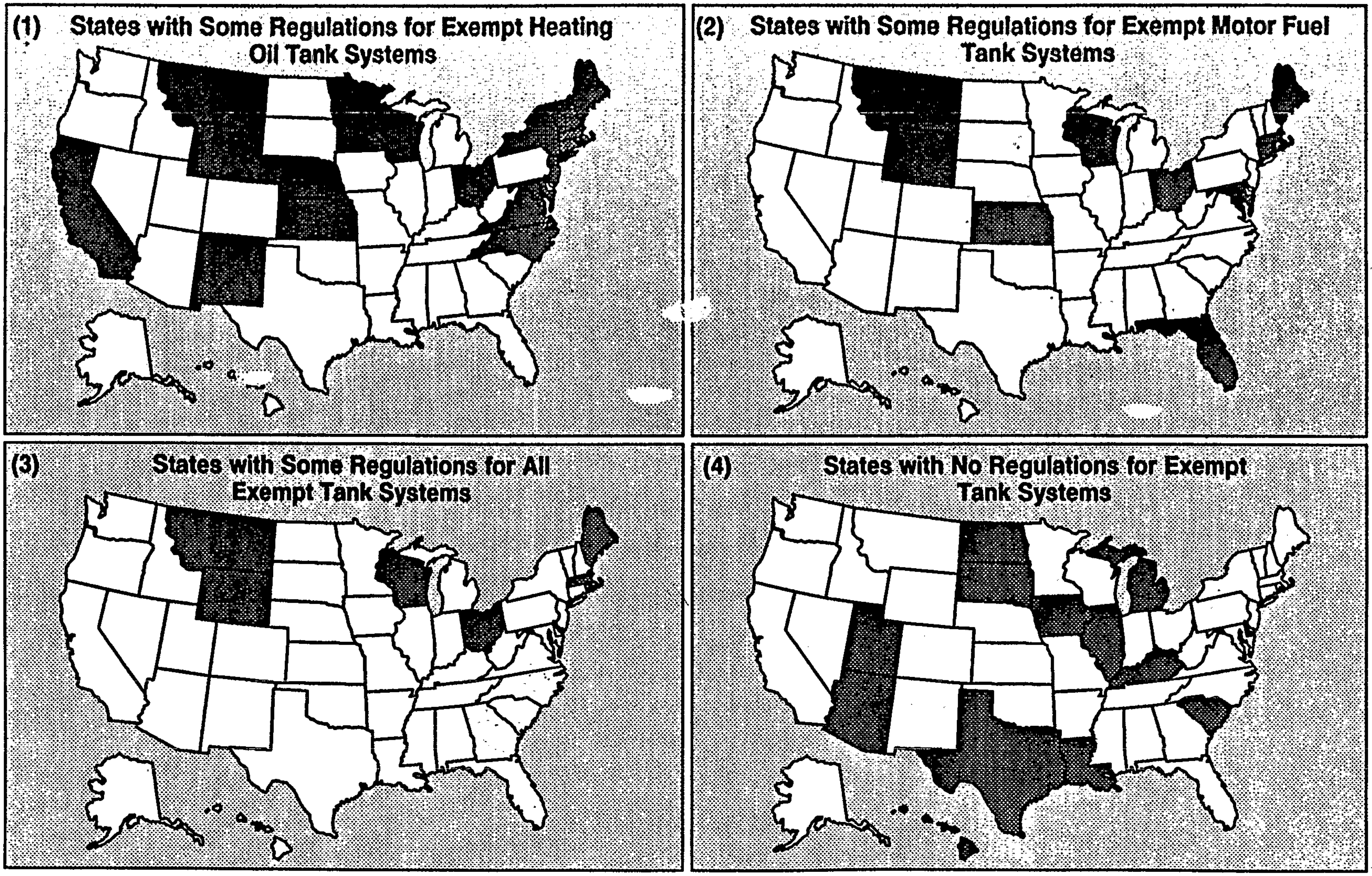
To assess the current level of state regulation of exempt heating oil and motor fuel tank systems, statutes and regulations from 34 states were examined and the tank systems exempt from regulation were identified (the remaining 16 states did not have an UST statute available for review). This review of state statutes and regulations revealed that at least 21 states currently consider exempt tank systems to be a problem and have included them to some extent in their regulatory framework.

Of the 34 states reviewed:

- Twenty states have some regulations for exempt heating oil tank systems (panel 1 of Exhibit 5-1);
  - Eighteen states have some regulations for residential heating oil tank systems, of which only eight regulate heating oil tank systems smaller than 1,100 gallons;
  - Eighteen states have some regulations for farm heating oil tank systems;
  - Seventeen states have some regulations for nonresidential heating oil tank systems;
- Ten states have some regulations for exempt motor fuel tank systems (panel 2 of Exhibit 5-1);
  - Eight states have some regulations for residential motor fuel tank systems under 1,100 gallons;
  - Eight states have some regulations for farm motor fuel tank systems under 1,100 gallons;
- Six states have some regulations for all exempt tank systems (panel 3 of Exhibit 5-1); and
- Thirteen states regulate the same USTs as Subtitle I (panel 4 of Exhibit 5-1).

Exhibit 5–1

State Regulation of Exempt Heating Oil and Motor Fuel Tank Systems[a]



[a] This following states did not have an UST statute available for review and do not appear in any of the categories of this exhibit: AL, AK, AR, CO, GA, ID, IN, MS, MO, NV, OK, OR, PA, TN, WA, and WV.

Source: ICF Incorporated analysis of state statutes and regulations (See Appendix D).

Several states' regulations mandate only notification/registration of the existence of tank systems and the reporting of releases when they occur, but do not mandate other technical standards (such as material of construction and leak detection). Furthermore, many of the state regulations covering exempt heating oil tank systems include only those tank systems with a capacity equal to or greater than a specified size, most commonly 1,100 gallons. A detailed list of existing state statutes that were reviewed is provided in Exhibit 5-2, at the end of this section.

State regulation of exempt tank systems was generally more extensive where the greatest number of exempt tank systems are located. For example, all of the states in the Northeast, except Pennsylvania and Delaware, have some regulations regarding exempt heating oil tank systems. (Exempt heating oil tank systems located in the Northeast comprise almost 50 percent of all exempt tank systems.)

An assessment of the present level of state regulation of exempt tank systems based on a review of state statutes and regulations must be qualified by the following observations:

- A review of state statutes and regulations does not necessarily indicate the actual amount of regulatory activity occurring.
  - -- Statutes are usually just the first step toward developing a state regulatory program. State and local regulatory agencies often have their own priorities for allocating resources that determine the level and scope of the regulatory program and enforcement that is undertaken. Thus, a statute may require regulation of exempt tank systems, but in practice a state implementing agency may concentrate its limited resources on tanks regulated under Subtitle I.
  - -- A state program may be operating under the authority of a statute not specific to underground tanks (such as a general groundwater protection statute) and the program exemptions may not be defined in the statute.
- Many of the statutes and regulations reviewed are quickly becoming outdated because there is currently a considerable amount of legislative activity concerning the regulation of USTs. In July 1987, there were 57 bills in 29 state legislatures concerned with underground tanks (API 1987).

Discussions with five states indicated that many states appear to be waiting to see whether Congress and EPA will address exempt tank systems before they pass new legislation (ICF 1988b).

5.2 LOCAL REGULATIONS

In addition to states, some local governments have developed UST regulatory programs that include exempt tank systems in their regulated community. Four of the more developed UST programs reviewed include: Dade Co., Florida; Barnstable Co., Massachusetts; Suffolk Co., New York; and Austin, Texas.

Of these four localities:

- Two have some regulations for all exempt tank systems;
- Two have some regulations for some exempt tank systems;
  - One has some regulations for all nonresidential exempt tank systems; and
  - One has some regulations for all exempt tank systems except heating oil tank systems under 1,100 gallons.

A detailed list of existing local statutes reviewed is provided on the last page of Exhibit 5-2.

5.3 SUMMARY

This review of the status of state and local regulatory UST programs reveals that some areas of the country already have some regulations pertaining to exempt tank systems. The extent of regulations varies among states and localities, with tank registration and notification of releases being the most common requirements. When technical standards are required for tank systems, such as a prohibition against the installation of new corrodible tank systems, or requirements for leak detection, they are generally limited to large (frequently for those tanks with a storage capacity of 1,100-gallons or more) nonresidential heating oil facilities. Residential, farm, and smaller nonresidential tank systems are frequently exempted from technical standards. Legislative and regulatory activity is continuing in many states.

EXHIBIT 5-2

STATE AND LOCAL REGULATION OF EXEMPT TANK SYSTEMS
(As Specified by State and Local Statutes and Regulations)

		Motor Fuel Tank Systems Under 1,100 Gallons are Regulated		Heating Oil Tank Systems Are Regulated			
State	Same Exemptions as Federal Regulations	Residential	Farm	Residential	Farm	Nonresidential	Comments
Arizona	X						
California				X			Residential underground heating oil tank systems of greater than 1,100 gallons capacity are regulated.
Connecticut			X		X	X	Nonresidential underground motor fuel tank systems are regulated. Nonresidential and farm underground heating oil tank systems of capacity greater than or equal to 2,100 gallons are regulated.
Delaware	X						
Florida			X				All nonresidential underground motor fuel tank systems of capacity greater than 550 gallons are regulated.
Hawaii	X						
Illinois	X						
Iowa	X						
Kansas		X		X		X	All underground tank systems except for tank systems individually owned and operated by agricultural farming systems are regulated.

Source: State Statutes and Regulations (see Appendix D)

EXHIBIT 5-2 (Continued)

State	Same Exemptions as Federal Regulations	Motor Fuel Tank Systems Under 1,100 Gallons are Regulated: Residential	Farm	Heating Oil Tank Systems Are Regulated: Residential	Farm	Nonresidential	Comments
Kentucky	X						
Louisiana	X						
Maine		X	X	X	X	X	All underground petroleum tank systems are regulated.
Maryland		X			X		Any underground motor fuel tank systems for a multi-family residence are regulated. Farm heating oil tank systems of 10,100 gallons or greater capacity are regulated. All tank systems are subject to leak detection and spill response requirements.
Massachusetts		X	X	X	X	X	All underground petroleum tank systems are regulated.
Michigan	X						
Minnesota				X	X	X	Underground heating oil tank systems greater than 1,100 gallons in capacity are regulated.
Montana		X	X	X	X	X	All underground petroleum tank systems are regulated.

EXHIBIT 5-2 (Continued)

State	Same Exemptions as Federal Regulations	Motor Fuel Tank Systems Under 1,100 Gallons are Regulated: Residential	Motor Fuel Tank Systems Under 1,100 Gallons are Regulated: Farm	Heating Oil Tank Systems Are Regulated: Residential	Heating Oil Tank Systems Are Regulated: Farm	Heating Oil Tank Systems Are Regulated: Nonresidential	Comments
Nebraska				X	X	X	Underground heating oil tank systems greater than 1,100 gallons in capacity are regulated.
New Hampshire				X	X	X	Underground heating oil tank systems greater than 1,100 gallons in capacity are regulated.
New Jersey				X	X	X	Nonresidential underground heating oil tank systems greater than 2,000 gallons in capacity are regulated. Residential underground tank systems greater than 2,000 gallons are subject to registration, inventory records and unaccountable losses requirements.
New Mexico				X	X	X	Underground heating oil tank systems greater than 1,100 gallons in capacity are regulated.
New York				X	X	X	Underground heating oil tank systems greater than 1,100 gallons in capacity are regulated. All tanks are subject to leak and spill response requirements.
North Carolina				X	X	X	Underground heating oil tank systems greater than 1,100 gallons in capacity are regulated.

EXHIBIT 5-2 (Continued)

State	Same Exemptions as Federal Regulations	Motor Fuel Tank Systems Under 1,100 Gallons are Regulated: Residential	Motor Fuel Tank Systems Under 1,100 Gallons are Regulated: Farm	Heating Oil Tank Systems Are Regulated: Residential	Heating Oil Tank Systems Are Regulated: Farm	Heating Oil Tank Systems Are Regulated: Nonresidential	Comments
North Dakota	X						
Ohio		X	X	X	X	X	All underground petroleum tank systems are regulated.
Rhode Island				X	X		Residential underground heating oil tanks are regulated if they are serving a residential building of more than 3 family units. Farm underground heating oil tanks 1,100 gallons capacity or greater are regulated. All tanks are subject to leak and spill response requirements.
South Carolina	X						
South Dakota	X						
Texas	X						

State	Same Exemptions as Federal Regulations	Motor Fuel Tank Systems Under 1,100 Gallons are Regulated: Residential	Farm	Heating Oil Tank Systems Are Regulated: Residential	Farm	Nonresidential	Comments
Utah	X						
Vermont				X	X	X	Underground heating oil tank systems greater than 1,100 gallons in capacity are regulated.
Virginia				X	X	X	Underground heating oil tank systems greater than 5,000 gallons in capacity are regulated.
Wisconsin		X	X	X	X	X	All underground tank systems are regulated.
Wyoming		X	X	X	X	X	No specific UST statute. No exemptions in more general environmental protection statute.

EXHIBIT 5-2 (Continued)

Selected Localities	Same Exemptions as Federal Regulations	Motor Fuel Tank Systems Under 1,100 Gallons are Regulated: Residential	Motor Fuel Tank Systems Under 1,100 Gallons are Regulated: Farm	Heating Oil Tank Systems Are Regulated: Residential	Heating Oil Tank Systems Are Regulated: Farm	Heating Oil Tank Systems Are Regulated: Nonresidential	Comments
Dade Co., Florida		X	X	X	X	X	All underground petroleum tank systems are regulated.
Barnstable Co., Massachusetts		X	X	X	X	X	All underground petroleum tank systems are regulated.
Suffolk Co., New York		X	X	X	X	X	Underground heating oil tank systems of less than 1,100 gallon capacity are exempt from some provisions.
Austin, Texas			X		X	X	All nonresidential underground tank systems are regulated.

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TECHNICAL APPENDICES

APPENDIX A

DETERMINATION OF POPULATION SIZE AND CHARACTERISTICS OF EXEMPT TANK SYSTEMS

This technical appendix supports Section 2, Description of Exempt Heating Oil and Motor Fuel Tank Systems,[1] by presenting the informatio and methodology used to derive the estimates of the population size, location, and other characteristics of exempt tank systems. Sections A.1 and A.2 describe the estimates of population size of exempt heating oil and motor fuel tank systems, respectively. These sections contain information regarding:

- Data sources,
- Computational methods,
- Input data and results, and
- Assumptions and sources of error.

Section A.3 describes the information used to support Section 2.3, characteristics of Exempt Tank Systems.

A.1 EXEMPT HEATING OIL TANK SYSTEMS

Section A.1 is divided into three sections. Sections A.1 1 and A.1.2 provide documentation of the estimates of the residential and farm heating oil sectors, respectively. Section A.1.3 describes the estimates for the three subsectors that combine to form the nonresidential sector.

A.1.1 Residential Heating Oil Sector

Exhibit A-1 shows the derivation of the estimate of exempt residential heating oil tank systems based on U.S. Census and Department of Energy data. There are an estimated 12,585,000 housing units in the U.S. heated with fuel oil (total in column C of Exhibit A-1). These housing units include facilities that use either aboveground or underground tanks. A frequency distribution of tank capacities is listed in column B. The number of housing units heated with fuel oil (including both aboveground and underground tanks) is shown in column C and is estimated for each tank size category by multiplying the number of housing units (12,585,000) by each of the relative frequencies in column B. The estimated number of exempt heating oil underground tank systems (column E) is then determined by multiplying the estimated number of housing units heated with fuel oil (column C) by the percentage of each category assumed to be buried underground (column D).

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[1] An exempt tank system includes a single exempt tank and its associated piping. See Appendix E for further elaboration of the definition.

Exhibit A-1

ESTIMATE OF THE POPULATION SIZE OF EXEMPT RESIDENTIAL HEATING OIL TANK SYSTEMS

[A] Tank Capacity (gallons)	[B] Frequency (%)[a]	[C] Housing Units Heated with Fuel Oil[b]	[D] Frequency (%) of Underground Tanks[c]	[E] Number of Exempt Tank Systems
≤ 249	7.6	956,000	0	0
250-300	48.3	6,079,000	5	304,000
301-799	14.5	1,825,000	40	730,000
≥ 800	4.8	604,000	95	574,000
Not Paying for Oil[d]	24.8	3,121,000	-- [e]	253,000
Total	100.0	12,585,000	--	1,861,000

[a] Includes both aboveground and underground tanks. Source: U.S. Department of Energy (1982).

[b] Source: U.S. Dept. of Commerce (Bureau of Census) and U.S. Dept. of Housing and Urban Development (1985).

[c] Source: SCS Engineers (see Exhibit A-4 for specific sources), Petroleum Marketers Association of America (1987), and Oil Heat Task Force (1987).

[d] Based on the individuals who responded to the census that they did not pay for their oil (and, consequently, did not know the size of the tank). These were assumed to be multiple-family residences.

[e] See Exhibit A-2 for detail on this category and derivation of the number of exempt tank systems at multiple-family residences.

The estimate for the number of the underground heating oil tank systems serving the 3,121,000 multiple-family housing units is derived in Exhibit A-2. The number of housing units heated with fuel oil is given in column C and is determined by multiplying the number of multiple-family housing units heated with fuel oil (3,121,000, from column C of Exhibit A-1) by the frequency of four sizes of multi-unit structures (column B). The number of exempt tank systems in each size category (column F) is determined by dividing the number of housing units heated with fuel oil, column C, by the number of housing units per heating oil tank, column D and mulitplying by the percentage in each category that is assumed to be buried, column E.

The geographic location of exempt residential heating oil tank systems was calculated in the same manner as the national population estimates. The total number of housing units heated with fuel oil in the U.S. (12,585,000, the total of column C of Exhibit A-1) was replaced with each of the regional numbers of housing units (column A of Exhibit A-3). The resulting regional estimates are included in column B of Exhibit A-3.

The major assumptions for these estimates are a source of potential error in the determination of the size of the entire population of exempt tank systems because of the large proportion of exempt tank systems which fall into this category. The major assumptions and potential sources of error are:

- Expert opinions. The percentage of heating oil tanks believed to be buried underground (for each tank size group and for each group of multi-family housing unit size) are expert opinions, as are estimates for the number of housing units per tank in the multiple-family residential estimate (see Exhibit A-4).

- Double Tank Systems. Heating oil storage systems (either aboveground or underground) using two or more small tanks for storage capacity may be counted as a single larger tank system, which could reduce the number of tanks in the smaller size categories and increase the number of tanks in larger size categories. It is difficult to estimate the effect of this source of error on the final estimate, but it is believed to be small.

- Sampling error. Sampling error associated with the census data occurs, because a total census or counting cannot be performed due to limitations of time and funding.

A.1.2 Farm Heating Oil Sector

The estimate of exempt farm heating oil tank systems, 43,000 tanks, is one of the few use sectors that has direct survey data available. This estimate was obtained by adding a question regarding underground tanks to the U.S. Department of Agriculture, National Agricultural Statistics Services' "1985

Exhibit A-2

ESTIMATE OF THE POPULATION SIZE OF EXEMPT MULTIPLE-FAMILY HEATING OIL TANK SYSTEMS

[A] Housing Units Per Facility	[B] Frequency (%)[a]	[C] Housing Units Heated With Fuel Oil	[D] Number of Housing Units Per Heating Oil Tank[b]	[E] Frequency (%) of Underground Tanks[c]	[F] Number of Exempt Tanks
2-4	31.0	967,500	2	15	73,000
5-9	12.0	374,500	3	80	100,000
10-19	12.1	378,000	15	95	24,000
≥ 20	44.9	1,401,000	25	100	56,000
Total	100.0	3,121,000[d]			253,000

[a] Source: U.S. Dept. of Commerce (Bureau of Census) and U.S. Dept. of Housing and Urban Development (1985).

[b] Source: Includes both aboveground and underground tanks, SCS Engineers (see Exhibit A-4 for specific sources).

[c] Source: SCS Engineers (see Exhibit A-4 for specific sources), Petroleum Marketers Association of America (1987), and Oil Heat Task Force (1987).

[d] From Column C of Exhibit A-1.

Exhibit A-3

ESTIMATES OF THE GEOGRAPHIC LOCATION OF EXEMPT UNDERGROUND RESIDENTIAL HEATING OIL TANK SYSTEMS

Geographic Region[a]	[A] Housing Units Heated with Fuel Oil[b]	[B] Number of Exempt Tank Systems[c]
Northeast	8,089,000	1,196,000
North Central	1,761,000	260,500
South	2,272,000	336,000
West	463,000	68,500
TOTAL	12,585,000	1,861,000

[a] See Exhibit 2-2 (page 2-5) for maps depicting geographic regions.

[b] Source: U.S. Dept. of Commerce (Bureau of Census) and U.S. Dept. of Housing and Urban Development (1985).

[c] Regional estimates of the number of exempt tank systems were calculated using the same methods as Exhibit A-1, except regional data on the number of housing units (column A of this exhibit) were used in column C of Exhibit A-1.

Exhibit A-4

LIST OF CONTACTS FOR SCS ENGINEERS' STORAGE TANK INSTALLERS SURVEY

Representatives from the companies and agencies listed below were contacted by telephone during December, 1986, and January, 1987, by SCS Engineers for estimations of the percentage of heating oil tanks that are buried underground at single-family and multi-family residences, as well as estimates of the number of multi-family housing units served per heating oil tank.

Tank Installers:

Brennan Oil and Heating Company, Incorporated; North Providence, RI
Charles Plumbing and Heating; Liverpool, NY
Charlie's Oil Company, Incorporated; Fall River, MA
Gill Services; Warwick, RI
Jim Trombly Plumbing and Heating; Manchester, NH
Oil Heat and Engineering, Incorporated; West Hartford, CT
Onondaga Heating; Syracuse, NY
Pittston Petroleum, Incorporated; Glastonbury, CT
Robert Shreve Fuel Company; Arlington, VA
Southern States Cooperative Incorporated; Chantilly, VA
Star Petroleum Company; Boston, MA
State Line Oil; Granby, CT
Supreme Fuel Company; Quincy, MA
The Plumbing and Heating Repair Company; Manchester, NH
Topar LP Oil Company; Fairfield, CT

Government Agencies:

Barnstable County Health and Environmental Department; Barnstable, MA
Connecticut Department of Environmental Protection; Hartford, CT
Kansas Department of Health and Environment; Topeka, KS
Minnesota Pollution Control Agency; St. Paul, MN

Farm Costs and Returns Survey." Not only did survey respondents indicate the presence of a tank, but also whether the tank was underground. The survey also provided regional estimates for underground farm heating oil tank systems.

The U.S. Department of Agriculture defines a farm as any place from which $1,000 or more of agricultural products were sold or normally would have been sold during the 1985 census year. These include farming, ranching, and related activities conducted by individuals, partnerships, corporations, cooperatives, prisons, hospitals, grazing associations, and Indian reservations.

Major potential sources of error include:

- Sampling error. The Farm Costs and Returns Survey provides 80 percent confidence boundaries with its weighted results. Sampling error occurs because a total census or counting cannot be performed due to limitations of time and funding.

- Possible Overlap with the Residential Estimate. It is possible that survey respondents may also have been considered in the residential estimate. The USDA Farm Costs and Returns Survey reports that there were 1.5 million farms. Resident owners/operators occupy 1.2 million of these farms. It is likely that some portion of these individuals may have reported their underground tank systems as being located at both farms and residences. The effects of the potential overlap between farms and residences on the estimate of the total exempt tank systems is minimal, however, because the entire farm heating oil estimate comprises only 1.4 percent of the entire population of exempt tank systems.

A.1.3 Nonresidential Heating Oil Sector

The number of underground nonresidential heating oil tank systems was determined by adding estimates for three subsectors: commercial, institutional, and government; manufacturing; and military. Methods used for each of these subsectors are described below.

Commercial, Institutional, and Government Heating Oil Subsector

Exhibit A-5 shows the derivation of the estimated number of commercial, institutional, and government heating oil tank systems. The number of heating oil tank systems at commercial, institutional, and government buildings, by the size of the floor space in the building, is presented in columns A and B of Exhibit A-5. The number of tank systems (including aboveground and underground) for each size category is determined by multiplying the number of tank systems (column B) by the frequency of tank size (column D). This result is then multiplied by the estimated percentage of each group that is buried underground (column E) to estimate the number of underground tanks (column F). The weighted mean percentage for the probability of tank burial for all

Exhibit A-5

ESTIMATES OF THE POPULATION SIZE OF UNDERGROUND COMMERCIAL, INSTITUTIONAL, AND GOVERNMENT HEATING OIL TANK SYSTEMS

[A] Building Size (Sq. Ft)	[B] Number of Tank Systems[c]	[C] Tank Size (Midpoint of grouping)	[D] Frequency Distribution[a] (%)	[E] Frequency of Tank Burial[b] (%)	[F] Number Exempt Tank Systems
5000 or less	300,000	275	35	5	5,250
		550	30	40	36,000
		1000	25	95	71,250
		2000	10	95	28,500
5001 to 10,000	165,000	275	3	5	248
		550	10	40	6,600
		1000	45	95	70,538
		2000	37	95	57,998
		5000	5	95	7,838
Over 10,000	269,000	All sizes	100	95	255,550
Total	733,000				539,772

Overall percentage of burial = (539,772)/(733,000) = 73.6%[d]

[a] Source: SCS Engineers (see Exhibit A-3 for specific sources).

[b] Source: SCS Engineers (see Exhibit A-3 for specific sources), Petroleum Marketers Association of America (1987), and Oil Heat Task Force (1987).

[c] Source: U.S. Department of Energy (1985).

[d] This figure is a weighted mean.

commercial, institutional, and government heating oil tank systems was determined to be 73.6 percent.

The geographic location of exempt commercial, institutional, and government tank systems was calculated in the same manner as the national population estimate, except the total number of tank systems (column B of Exhibit A-5) was replaced with each of the regional numbers of tank systems. A summary of the regional estimates is included in Exhibit A-6.

The major assumptions and sources of error associated with the estimate of exempt commercial, institutional, and government heating oil tank systems are as follows:

- Sampling Error. Sampling error or lack of representativeness attributable to the Department of Energy's survey data.
- Potential Double Counting. Possible overlap between those persons who use their residences for commercial purposes, potentially including the estimates in both the residential and commercial data.
- Expert Opinions. Expert opinions are used to estimate the frequency distribution of tanks, based on tank size, that are believed to be buried underground.
- Double Tank Systems. Heating oil storage systems (either aboveground or underground) using two or more small tanks for storage capacity may be counted as a single larger tank, which could reduce the number of tanks in the smaller size categories and increase the number of tanks n larger size categories. It is difficult to estimate the effect of this source of error on the final estimate, but it is believed to be small.

Manufacturing Heating Oil Subsector

The estimate of the number of exempt heating oil tank systems located at manufacturing facilities was calculated from the total storage tank capacity for heating fuels consumed on premises (2,562,000,000 gallons; National Petroleum Council 1984) and estimates for the average tank size. The average tank size at industrial facilities from three state notification data bases was approximately 10,000 gallons (California- 15,000; Maine- 7,000; and Minnesota- 10,000). The estimate of the number of heating oil tank systems was calculated by dividing the total storage capacity by the average tank size [(2,562,000,000 gallons)/(10,000 gallons per tank) = 256,200 tanks]. The number of these tank systems that are buried underground was calculated by multiplying the number of tank systems times the probability of their being buried. This probability was assumed to be 73.6 percent, the same as the mean probability estimated for the commercial, institutional, and government sector (see Exhibit A-5). This resulted in an estimate of 189,000 exempt manufacturing heating oil tank systems in the U.S.

Exhibit A-6

ESTIMATES OF THE GEOGRAPHIC LOCATION OF EXEMPT COMMERCIAL, INSTITUTIONAL, AND GOVERNMENT HEATING OIL TANK SYSTEMS

Region	[A] Number of Heating Oil Tank Systems[a] (all sizes)	[B] Number of Exempt Tank Systems
Northeast	318,000	234,000
North Central	129,000	95,000
South	236,000	174,000
West	50,000	37,000
TOTAL	733,000	540,000

[a] Source: U.S. Department of Energy (1985).

No data were available to directly estimate the regional storage capacity of heating oils at manufacturing facilities; however, data were available regarding regional consumption of heating oils at these facilities. The geographic location of exempt manufacturing heating oil tanks was estimated by multiplying the estimated number of exempt tank systems for this use sector--189,000-- by the relative amount (%) of heating oil consumed at manufacturing facilities in each region. The relative consumption of heating oils at manufacturing facilities, by region, was: 43.4 percent in the Northeast, 12.0 percent in the North Central, 34.8 percent in the South, and 9.8 percent in the West (U.S. Department of Commerce 1985). This resulted in an estimated 82,000 exempt heating oil tank systems in the Northeast; 66,000 in the South; 23,000 in the North Central, and 18,000 in the West.

The major assumptions and sources of error for estimating the number of exempt manufacturing heating oil tanks are:

- Estimate of Probability of Burial. The estimate of the probability of burial is the same as that used for the commercial, institutional, and government sector. It is possible that the percentage of tanks buried in the manufacturing sector is higher than 73.6 because of the generally larger tanks found at manufacturing facilities. (Larger tanks are more likely to be buried than smaller tanks). However, a 100 percent assumed rate of burial for this sector would add only 67,200 tank systems to the estimate, which constitutes only 2.2 percent of the estimated 3.1 million exempt tank systems.

- Average Tank Size. The estimate of average heating oil tank capacity was applied uniformly across the U.S. based on data from three states.

- Applicability of Consumption Data. The regional total storage capacity was assumed to be proportional to regional consumption of fuel oil.

- Sampling Error. No sampling or other error estimates have been published regarding consumption or storage of heating oil.

Military Heating Oil Subsector

There are no calculations or quantitative discussions involved in the estimate of exempt heating oil tank systems for the military. All the information regarding this subsector is based on undocumented reports from the four branches of the military services. In most cases, the numbers reported were given as minimum estimates. Exhibit A-7 contains a summary of the information reported by the military services.

A.2 EXEMPT MOTOR FUEL TANK SYSTEMS

Section A.2 contains information regarding the estimates of exempt motor fuel tank systems. Section A.2.1 describes exempt farm motor fuel tank systems. Section A.2.2 describes exempt residential motor fuel tank systems.

Exhibit A-7

REPORTS OF EXEMPT MILITARY TANK SYSTEMS USED TO HEAT RESIDENTIAL BUILDINGS

Branch	Reported Number Exempt Heating Oil Tank Systems[a]	Comments[a]
Army	20,000	Reported as a minimum
Navy	10,000	Ranges from 6,000-14,000
Air Force	12,200	Reported as a minimum
Marines	0	Claim to have removed all exempt heating oil tanks
Total	42,200	

[a] Source: Interviews conducted by SCS Engineers with representatives of each branch of the armed services (USA 1986; USN 1986; USAF 1986; USMC 1986).

A.2.1 Farm Motor Fuel Sector

The number of exempt farm motor fuel tank systems was estimated as the average of estimates from two separate surveys: the 1985 Farm Costs and Returns Survey (U.S. Department of Agriculture unpublished data) and the Motor Fuels Storage Tanks Survey (USEPA 1986a).

The 1985 Farm Costs and Returns Survey is discussed in Section A.1.2 of this appendix. For the second estimate, from "Underground Motor Fuels Storage Tanks: A National Survey," the authors of the report acknowledge that the statistical design was optimized to produce the best estimate of commercial motor fuel USTs (which tend to be most concentrated in urban areas). Consequently, the experimental design used was sub-optimal for estimating the number of exempt farm motor fuel tank systems (which tend to be located in rural areas). Such a design, however, is not expected to create a statistically biased point estimate, but would likely increase the variance around the point estimate. Therefore, this estimate was also used for this study.

Estimates of the geographic location of exempt farm motor fuel tank systems were available only from the 1985 Farm Costs and Returns Survey. The regional distribution of these tank systems was determined by multiplying the regional distribution percentage of exempt farm motor fuel tank systems from the 1985 Farm Costs and Returns Survey by the estimate for this entire sector (260,000 USTs). The regional distribution was as follows: Northeast, 10.6 percent; North Central, 38.4 percent; South, 14.5 percent; and West, 36.5 percent.

Sources of error for the Farm Costs and Returns Survey are discussed in section A.1.2 of this appendix. For the EPA survey, sampling error associated with the survey data occurs, because a total census or counting cannot be performed due to limitations of time and funding.

A.2.2 Residential Motor Fuel Sector

The only data available on exempt residential motor fuel tank systems was found in the state notification databases for California, Maine, and Wisconsin. A ratio of the number of exempt motor fuel tank systems registered within each state to the number of housing units for that state was calculated (column C of Exhibit A-8 is the quotient of column B divided by column A). The weighted mean of these three ratios was used as the ratio of underground motor fuel tanks to households for the country as a whole. This mean was multiplied by the number of housing units in the U.S. to estimate the entire U.S. population of exempt residential motor fuel tank systems. The data for these calculations is presented in Exhibit A-8.

A.3 STATE UST NOTIFICATION DATA BASES

Data from three state UST notification data bases (California, Maine, and Montana) were used to analyze tank characteristics. These states were selected because of the limited availability of relevant data, rather than based on statistical sampling techniques. Furthermore, officials from each of

Exhibit A-8

ESTIMATED POPULATION SIZE OF EXEMPT RESIDENTIAL MOTOR FUEL TANK SYSTEMS

	[A] Number of Occupied Housing Units[a]	[B] Number of Registered Exempt Residential Motor Fuel Tank Systems[b]	[C] Ratio of Motor Fuel Tanks to Housing Units
California	9,675,000	2,097	0.00022
Maine	431,000	323	0.00075
Wisconsin	1,748,000	9,989	0.00571
U.S. Total	87,489,000	---	---

Weighted Mean[c] of the three State Ratios = 0.00105

U.S. estimate = (Weighted Mean of Ratios) x (Total U.S. Housing Units)

= .00105 x 87,489,000 = 91,900

[a] Source: U.S. Department of Commerce (1987).

[b] Sources: State UST Notification Data Bases from: California State Water Resources Control Board, Dec. 1986; Maine Dept. of Environmental Protection, Dec. 1986; and Wisconsin Dept. of Industry, Labor, and Human Relations, Feb. 1987.

[c] The mean ratio is weighted by the number of occupied housing units per state as a percentage of the total number of occupied housing units in the three states considered.

these states acknowledge that the data are not complete and that residential and rural owners of small exempt tank systems (less than 1,000 gallons) are the least likely to register their tank(s).

Despite the lack of solid grounding based on statistical sampling theory, the information available from analysis of tank characteristics of these three data bases was used for describing exempt tank system characteristics and comparing them with those of USTs regulated under Subtitle I. The lack of statistical sampling methods does not mean data are inaccurate or invalid -- only that the degree of accuracy and validity are unknown. UST program officials from other states and localities were contacted to augment these data.

Exhibit A-9 summarizes exempt tank system registration data for California, Maine, Montana, and Wisconsin.

EXHIBIT A-9

SUMMARY OF THE NUMBER OF REGISTERED EXEMPT TANK SYSTEMS

	California	Maine	Montana	Wisconsin
Underground Heating Oil Tank Systems:				
Residential	364	3,802	--	14,815
Agricultural	129	305	--	569
Nonresidential	688	5,810	--	11,499
Subtotal	1,181	9,919	973	28,602
Underground Motor Fuel Tank Systems:				
Residential	2,097	323	--	9,989
Agricultural	2,097	834	--	30,078
Subtotal	22,021	1,157	4,737	40,067
Total Registered Exempt Tank Systems	23,202	11,076	5,710	68,669
Total Regulated USTs	124,786	9,313	10,401	63,052

Source: State UST Notification Data Bases from: California State Water Resources Control Board, Dec. 1986; Maine Dept. of Environmental Protection, Dec. 1986; Montana Dept. of Health and Environmental Science, March 1987; and Wisconsin Dept. of Industry, Labor, and Human Relations, Feb. 1987.

APPENDIX B

SOURCES OF INFORMATION ABOUT EXTENT OF RELEASES

This appendix contains descriptions of the major sources of information used to document the extent of releases from exempt tank systems.

EPA State and Local Release Incident Survey (National Data Base)

This data base, containing records from 1970 to 1985, provides information on more than 13,000 reported releases from both regulated USTs and exempt tank systems, making it the most comprehensive source of information currently available on releases from underground storage tanks. Information is provided on approximately 2,000 releases from exempt tank systems, 500 releases from USTs containing hazardous wastes, and more than 10,000 releases from regulated USTs. The information was collected primarily by visits to state offices to review case files, but in some states, the data were obtained by telephone. The information includes only those releases detected and reported to state or local agencies and is not a statistically valid sample of tank releases or of all underground tank systems. As a result, it is not possible to assess the overall accuracy or validity of the data, nor is it possible to develop a quantitative measure of confidence.

Report on Releases from Federally Exempt Heating Oil and Motor Fuel Tank Systems in Maryland

In November 1987, representatives of EPA and ICF Incorporated interviewed officials from Maryland's Department of the Environment to obtain both qualitative and quantitative information relating to releases of heating oils and motor fuels from federally exempt tank systems. The information collected included 154 reports from Underground Leak Summary Forms of tank system failures from September 11, 1985, to August 25, 1987, and 904 reports from Initial Oil Spill Report Data Forms of tank system failures from late 1985 to August 31, 1987. The two types of forms account for a total of 989 distinct cases.

New York State's Spill Response Data Base

Data from the New York State Department of Environmental Conservation (NYSDEC) spill response data base, compiled under the mandate of New York's Petroleum Bulk Storage and Navigation Regulations, contain considerable information on spills involving heating oil. The data covers 15,597 spills recorded between October 1985 and September 1987. Of the total, 3,551 spills (23 percent) involved fuel oil Nos. 2, 4, or 6. A major limitation of the data, however, is that the spill reports do not indicate if the release was from an underground or an aboveground tank. Additional information about these spills was obtained through interviews with representatives of NYSDEC, Bureau of Spill Prevention and Response. These interviews were conducted by

EPA and ICF Incorporated during November 1987. The information was used to augment data from the National Data Base and from Maryland.

Summary Notes of Meeting with State and Local Officials Concerning Federally Exempt Tank Systems

On December 2, 1987, EPA's Office of Underground Storage Tanks held a meeting of representatives of the UST programs in Connecticut, Maine, Minnesota, Rhode Island, Wisconsin, Barnstable County (MA), and Suffolk County (NY).. The purpose of the meeting was to allow these state and local UST program representatives to share their experiences and data on federally exempt tank systems. The available information varied from program to program, but included a limited number of descriptions of releases from exempt tank systems and the environmental effects of those releases, estimates of the total numbers of releases and well contaminations from exempt tank systems, and observations on the extent of exempt tank system releases from the farm and residential sectors. A pooling of the data from these sources was not possible because of the varied data collection methodologies and release reporting requirements.

Tank Corrosion Study in Suffolk County (NY)

This study is a joint EPA/Suffolk County investigation of corrosion as a cause of releases from underground steel tanks. As existing tank systems were removed for replacement or for other reasons, a contractor examined them for evidence of corrosion or perforations. The latest available draft interim report for this study (Pim 1988) presents an assessment of 89 federally exempt tank systems removed from February 1987 through January 1988. The study includes both exempt tank systems and regulated USTs that contained heating oil and motor fuel. The previous interim report (Pim 1987) summarizes the results of the first 200 tanks (including both exempt tank systems and regulated USTs) removed for this study.

APPENDIX C

POTENTIAL IMPACTS ON HUMAN HEALTH AND THE ENVIRONMENT FROM PRODUCTS RELEASED FROM EXEMPT HEATING OIL AND MOTOR FUEL TANK SYSTEMS

This appendix provides a more detailed assessment of the discussion in Section 4 concerning the potential human health risks associated with the release of petroleum products from exempt tank systems. In assessing these health risks, it is necessary to evaluate (1) the composition of the petroleum products and the toxicities of their constituents, (2) how released products may be transported through the environment to points of human contact, and (3) the adverse health effects that may result from exposure to these substances. Section C.1 describes the products found in exempt tank systems and summarizes the toxic effects that have been associated with the products and their constituents; Section C.2 discusses the likely environmental transport and fate of substances released from underground storage tank systems, and how these releases may lead to contamination of air, soil, surface water, and ground water; and Section C.3 discusses the possible ways humans may come into contact with released petroleum products, and the potential health risks associated with these exposures.

C.1 DESCRIPTION OF MOTOR FUELS AND HEATING OILS AND THEIR POTENTIAL HEALTH EFFECTS

The first step in assessing potential health risks is to determine the composition of the released products and the toxicities of their constituents. This is a difficult task for two reasons. First, although it is known that exempt tank systems are used to store a variety of petroleum products, including gasoline, diesel fuel, and fuel oils Nos. 1, 2, 4, 5, and 6, the exact compositions of these products are unknown. It is possible, however, to estimate likely compositions by analyzing the refining process and reviewing available data of selected constituents. Second, the toxicities of even the known constituents are generally not well studied. Most of the available studies examine the effects resulting from skin contact with undiluted fuels rather than the effects resulting from eating and drinking very dilute fuels, the most significant means of exposure for humans. It is possible, however, to review the toxicity information available for some of the constituents. The description of the products, therefore, begins with a discussion of the manufacture of petroleum products and some basic properties of hydrocarbons in Section C.1.1., and continues with a discussion of the toxicities of the fuels and some of their constituents in Section C.1.2.

C.1.1 Manufacture of Petroleum Products

Crude petroleum is composed mainly of hydrocarbons (compounds containing carbon and hydrogen) and small amounts of nitrogen, sulfur, oxygen, and heavy metals. Three major classes of hydrocarbons are present: (1) paraffins, which are straight or branched chains of carbon atoms, (2) cycloparaffins, which are closed chain or "cyclic" saturated hydrocarbons, and

(3) aromatics, which are "cyclic" unsaturated hydrocarbons. Some adverse health effects have been associated with smaller paraffin compounds and cycloparaffins; the aromatic compounds are generally regarded as the most significant toxic components of the fuel oils.

In the manufacture of petroleum products, the crude petroleum is distilled into several refinery streams. All of the streams have the three classes of hydrocarbons present, but in different proportions. The hydrocarbons distilling from a representative sample of crude oil are shown in Exhibit C-1.

As the distillation process begins, the more volatile, lower molecular weight hydrocarbons, with lower boiling points, distill first and are the precursors of gasoline. These compounds are predominately hydrocarbons containing 3 to 11 carbon atoms and tend to be mostly short-chain paraffins and small cycloparaffins. A lower proportion of aromatics are present, and most of these have one or two rings or "nuclei" (mononuclear aromatic compounds, such as benzene, toluene, and xylene).

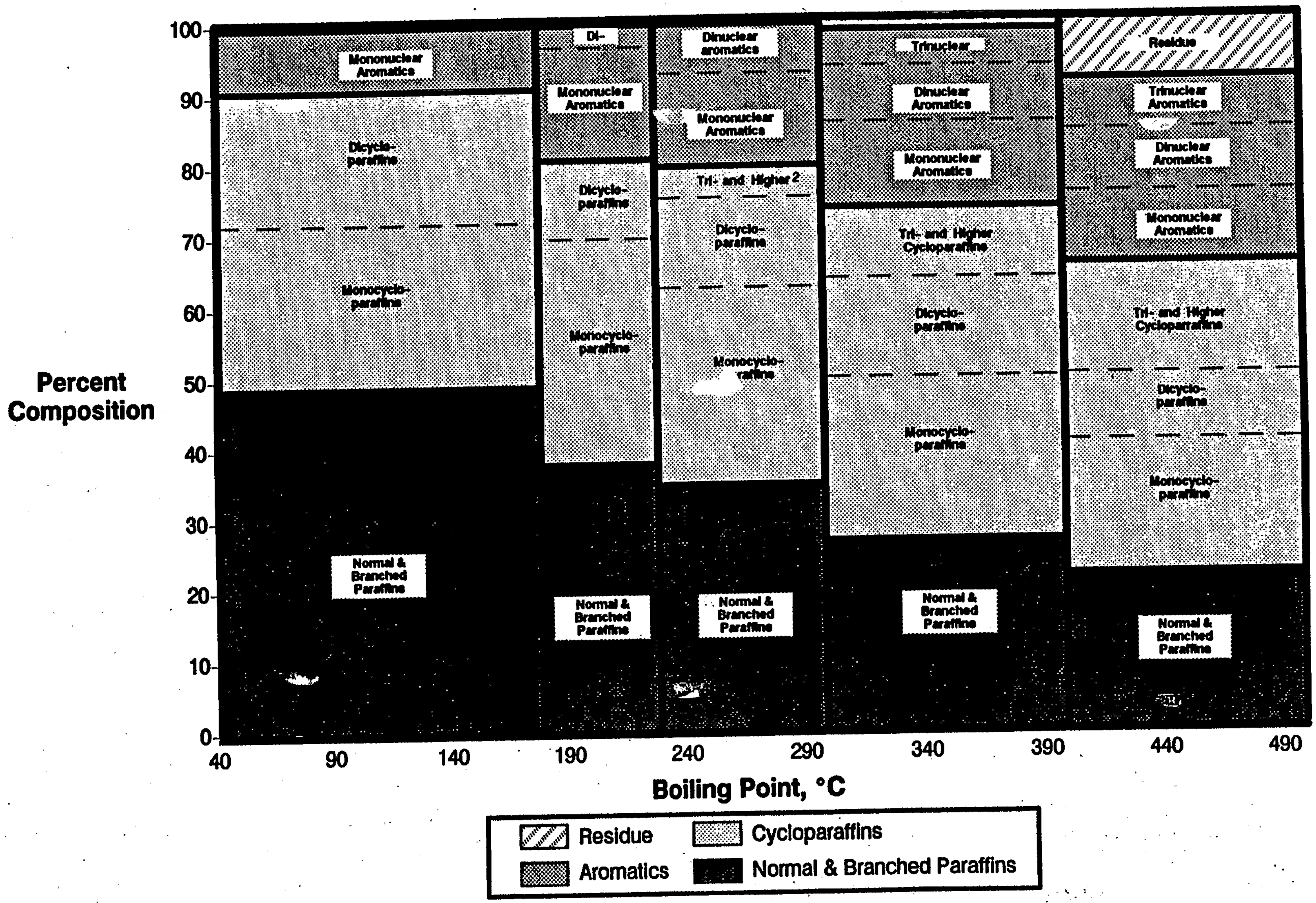
The middle range molecular weight molecules, with mid-level boiling points, distill next and make up what is referred to as the middle distillate fraction, from which kerosene, diesel fuel, and fuel oil Nos. 1 and 2 are derived. These hydrocarbons contain predominantly 9 to 25 carbon atoms and tend to be mostly longer-chain paraffins than those found in gasoline and larger cycloparaffins. The proportion of aromatics is higher than in gasoline and the compounds present contain more rings or "nuclei" (polynuclear aromatic hydrocarbons, PAHs). That is the aromatic fraction of the middle distillates tends to have a lower percentage of single-ring compounds (e.g., benzene) than gasoline and a higher percentage of multiple-ring compounds (PAHs), although not as high as the residual fuels.

Relatively non-volatile, high molecular weight compounds with high boiling points remain at the end of the distillation process. Fuel oil Nos. 4, 5, and 6 come from this residual stock. The hydrocarbons making up the residual fuels tend to be very large and complex. The paraffins comprise less and less of the total hydrocarbons present, and the concentrations of large cycloparaffins and large aromatics (PAHs) are high. These fuels, as a class, tend to have a higher concentration of PAHs than either gasoline or the middle distillates; compounds containing four and five rings or more are not uncommon.

The only standardization requirements for the final fuel products concern their physical properties. In some cases, the distillate fractions conform to the fuel specifications outlined by American Society for Testing and Materials without further modification, and are used as "straight run" fuels. In others, the fractions may undergo additional processing, such as further refining, blending with one or more refinery streams, or, in some cases, addition of agents such as anti-corrosion or combustion-enhancing compounds. Because the composition of hydrocarbons is different in every crude oil and, consequently, in every distillation stream, and because many additive formulations are patented and new formulations are constantly being created, it is virtually impossible to identify all constituent concentrations

Exhibit C–1

Relative Concentrations of Hydrocarbons Present in a Representative Sample of Crude Oil



Source: ICF 1988b

1 Dinuclear aromatics

2 Tri- and higher cycloparaffins

in petroleum products. The actual compositions of fuels fluctuate depending on the source of the crude, the refining processes utilized, and the streams blended to produce the final products.

C.1.2 Potential Health Effects Resulting from Exposure to Petroleum Products and Their Constituents

This section discusses health effects that may be associated with exposures to the fuels and their constituents. A summary of these health effects is shown in Exhibit C-2. Information on specific constituents has been cited, because toxicity data on the fuels as mixtures are often limited. Representative concentrations for some of the constituents are shown in Exhibit C-3. Actual concentrations of these substances in the fuels can fluctuate dramatically. Available health-based criteria (e.g, cancer potency factors, reference doses, and maximum contaminant levels (MCLs)) for the constituents are presented in Exhibit C-4.

Gasoline

Gasoline, which has been studied extensively study under EPA's RCRA Subtitle I regulatory program, is already classified as a probable human carcinogen (API 1983, USEPA 1985a, ICF 1988). As a result, this discussion of the toxicities of products stored in exempt tank systems focuses primarily on heating oils, which account for most of the petroleum products stored in exempt tank systems.

Middle Distillate Fuels

Some members of the middle distillate fuel family (in particular, fuel oil No. 2 and diesel fuel) have been shown to be weak to moderate carcinogens when applied to the skin of animals (USEPA 1985e). No studies examining cancer effects following inhalation or ingestion were found (USEPA 1985e). Non-cancer effects of the middle distillates include skin irritation and, at high doses, hepatic toxicity (USEPA 1985e). In humans, tubular necrosis was reported in one adult who used diesel fuel to clean his hands and arms for several weeks, and acute renal failure was observed in another who used diesel fuel as a shampoo (Crisp et al. 1979; Barrientos et al. 1977).

Some of the compounds in the middle distillate fuels that may be of toxicological concern are aromatic compounds, including noncarcinogenic PAHs, such as naphthalene; other PAHs, such as benzo(a)anthracene and benzo(a)pyrene, which have been shown to be carcinogenic in animals; and cresols and phenols. Three of the toxic aromatic constituents of gasoline, namely toluene, xylene, and ethylbenzene, are also found in the middle distillates, but are present in lower concentrations than in gasoline (Exhibit C-3).

Exhibit C-2

POTENTIAL ADVERSE HEALTH EFFECTS ASSOCIATED WITH EXPOSURES TO SOME CONSTITUENTS OF MOTOR FUELS AND HEATING OILS

FUEL TYPE	CONSTITUENT	POTENTIAL HEALTH EFFECTS
Gasoline	Benzene	Human carcinogen
Middle Distillates	Polynuclear aromatic hydrocarbons (PAHs):	
(Kerosene, diesel fuel, fuel oil Nos. 1 and 2, and some blends of No. 4)	naphthalene	Causes malaise, tremors, vomiting, and eye damage
	benzo(a)anthracene	Probable human carcinogen
	benzo(a)pyrene	Probable human carcinogen
	Cresols and phenols	Irritates skin, mucous membranes, and eyes May be cancer promoters
Residual Fuels	PAHs:	
(Fuel oil Nos. 5 and 6, and most blends of No. 4)	benzo(a)anthracene	Probable human carcinogen
	benzo(a)pyrene	Probable human carcinogen
	chrysene	May be a carcinogen
	Catalytically cracked clarified oil	Potent carcinogen in animals

Source: Based on literature review performed by ICF Incorporated.

EXHIBIT C-3

CONCENTRATIONS (G/L) OF SELECTED TOXIC CONSTITUENTS OF HEATING OILS

Constituent	Fuel Oil No.2[a]		Fuel Oil No.6[b]	
Benzene	BDL(0.1)	c		
Toluene	0.62	c		
Xylenes	2.5	c		
	0.62	d		
Ethylbenzene	0.40	c		
	0.28	d		
Phenol	0.007	d		
	BDL(1.0)	c		
Cresols	0.054	d		
PAHs				
Naphthalene	2.5	c	0.97	e
	2.7	d		
Benzo(a)pyrene	0.0006	f	0.04	f
	0.00003	g		
	BDL(1.0)	c		
Benzo(e)pyrene	0.0001	f	0.01	f
Benzo(a)anthracene	0.001	f	0.09	f
	BDL(1.0)	c		
Phenanthrene	1.0	c	0.46	f
	1.5	d		
	0.43	f		
Chrysene	0.0014	f	0.19	f
	BDL(1.0)	c		

EXHIBIT C-3

CONCENTRATIONS (G/L) OF SELECTED TOXIC CONSTITUENTS OF HEATING OILS

(Continued)

Constituent	Fuel Oil No.2[a]		Fuel Oil No. 6[b]	
2-Methylnapthalene	7.0	c	4.5	e
	6.7	d		
Pyrene	BDL	d	0.022	f
	0.041	f		
	BDL(1.0)	c		
Fluoranthene	BDL	d	0.23	f
	0.04	f		
	BDL(1.0)	c		
Heavy Metals				
Arsenic	0.003	h	0.003	h
Lead	0.001	h	0.005	h

a Derived from weight percentages using 0.9 as the specific gravity of fuel oil No. 2.
b Derived from weight percentages using 1.0 as the specific gravity of fuel oil No. 6.
c Oil Heat Task Force 1987. Average of reported levels for three samples of fuel oil No. 2. BDL indicates "below detection limit" and the instrument detection limits given in parentheses. These samples are useful because they provide an "upper-bound" concentration at which the constituent was not observed.
d Thomas 1984. No detection limit given. These samples are useful because they provide an "upper-bound" concentration at which the constituent was not observed.
e Neff and Anderson 1981.
f Pancirov and Brown 1975.
g Tomkins and Griest 1987.
h GCA 1983.

EXHIBIT C-4

HEALTH-BASED CRITERIA FOR SELECTED TOXIC CONSTITUENTS OF MOTOR FUELS AND HEATING OILS

Constituent	Cancer Potency Factor[a] $(mg/kg\text{-}day)^{-1}$	Reference Dose[b] (mg/kg/day)	Maximum Contaminant Level[c] (ug/l)
Benzene	0.052 d		5.0
Toluene		0.3 e	
Xylenes		2.0 f	
Ethylbenzene		0.1 g	
Benzo(a)pyrene h	11.5 d		
Phenol		0.04 i	
Arsenic	15. d		
Lead		0.0014 c	

a Cancer potency factors are used to estimate excess cancer risks associated with lifetime exposures to potential carcinogens.
b Reference doses are estimates of the level of daily exposure that is likely to be without appreciable risk of adverse effects.
c MCLs are concentrations that EPA has set as acceptable for public water supplies.
d USEPA 1985b.
e USEPA 1984a.
f USEPA 1986c.
g USEPA 1985c.
h This value is currently under review.
i USEPA 1985d.

<u>Polynuclear Aromatic Hydrocarbons (PAHs)</u>. Several specific PAHs have been detected in the middle distillates. These include naphthalene, benzo(a)anthracene, and benzo(a)pyrene (Exhibit C-3). Health effects of these PAHs are described below. Because the concentrations of aromatic compounds are so high in the residual fuels, it is likely that these compounds do not represent all of the PAHs present.

Naphthalene. Naphthalene is present in significant concentrations in the middle distillates (Exhibit C-3). This compound is toxic to humans by any route of exposure. There is no evidence that naphthalene is carcinogenic; noncancer effects following chronic ingestion or inhalation include malaise, tremors, and vomiting (IARC 1983; 1984). Eye damage, such as injuries to the cornea and opacities of the lens, may also occur (USEPA 1982).

Benzo(a)anthracene and Benzo(a)pyrene. Benzo(a)anthracene and benzo(a)pyrene have been detected at very low concentrations in several samples of fuel oil No. 2 (Tomkins and Griest 1987; Pancirov and Brown 1975). Both of these compounds are classified as probable human carcinogens (USEPA 1986b).

<u>Cresols and Phenols</u>. Cresols are irritating to the skin, mucous membranes, and eyes. They can impair liver and kidney function, and can cause central nervous system and cardiovascular disorders. Phenol is toxic to the liver and kidneys (USEPA 1985f). Dermal applications of phenols and cresols have been reported to increase the number of skin tumors in mice when administered after the application of cancer-causing agents (Boutwell and Bosch 1959; USEPA 1980). Data are insufficient to assess the toxicity of cresols by oral exposure (USEPA 1984b).

Residual Fuels

The exceptionally viscous residual fraction of distilled petroleum is often blended with less viscous distillation streams so that the final product meets the performance specifications designated for fuel oils Nos. 4, 5, and 6. Blending agents include catalytically cracked clarified oil, catalytic reformer fractionator residue, straight run gas oil, heavy vacuum gas oil, and heavy catalytically cracked distillate (USEPA 1986b). While no reports examining carcinogenic effects of the residual fuels were found, several reports indicated that at least two of the blending stocks used in their production are carcinogenic in mice (USEPA 1985b, API 1985). These blending agents are cracked bunker fuel and catalytically cracked clarified oil. The latter is recognized as one of the most carcinogenic materials in petroleum refinery (USEPA 1985b; API 1985). Noncancer health effects observed in animals following oral administration of fuel oil No. 6 include lethargy and intestinal irritation. Chronic dermal exposures can cause skin irritation (USEPA 1985b).

The constituents of most concern in the residual fuels are the PAHs. Although they are not very water soluble, PAHs are present in higher concentrations in residual fuels than in gasoline or the middle distillates.

Polynuclear Aromatic Hydrocarbons (PAHs). At least two of the PAHs, namely benzo(a)pyrene and benzo(a)anthracene, that may be present in fuel oil No. 6 are classified as probable human carcinogens. There is limited evidence that a third PAH, chrysene, is also carcinogenic in animals (IARC 1983). PAHs have a much higher concentration in residual fuels than in the middle distillates. In addition, because the residual fuels tend to have high concentrations of aromatic compounds, other PAHs than the ones listed here are likely to be present but have not been reported.

Heavy metals. The heavy metals, such as arsenic, lead, and zinc, have been detected at low concentrations in samples of fuel oil Nos. 4 and 6 (GCA 1983). Arsenic is a human carcinogen both by inhalation (lung cancer) and by ingestion (skin cancer) (USEPA 1986b).

In this section some of the known toxic constituents of the fuels have been discussed. This discussion is not intended to imply that these are the only toxic constituents present. In fact, because little is known about these fuels, it is likely that these constituents represent only a portion of the hazardous components in these complex mixtures.

C.2 FATE AND TRANSPORT OF RELEASED PETROLEUM PRODUCTS

The adverse environmental and human health effects of products released from exempt tank systems depend on how long these contaminants are in the environment and the extent to which they reach human or environmental receptors in harmful concentrations. This section discusses factors that affect how contaminants move in the environment and implications regarding the overall hazard resulting from exempt tank systems releases.

The fate and transport of released petroleum products is affected by a wide variety of site-specific and constituent-specific factors. As a result, conclusions that are generally true for petroleum releases may not be true for all releases. The major concerns, discussed below, are transport of free product in the unsaturated zone (Section C.2.1), transport of free product on top of the ground water (Section C.2.2), transport of dissolved product in the ground water (Section C.2.3), transport of vapors (Section C.2.4), and processes that affect the fate of contaminants in the environment (Section C.2.5).

C.2.1 Transport of Free Product in the Unsaturated Zone

General Discussion

Transport of motor fuels and heating oils in the unsaturated zone of the subsurface is characterized by a gravity-driven downward flow with some lateral spreading of the plume because of differences in soil permeability. A variety of physical and chemical properties of both the free product and the environment into which it is released affect the movement of free product in the unsaturated zone (i.e., above the water table). The primary physical properties of the products that affect transport of petroleum contaminants released into the environment are the viscosity and density of the free product. Physical characteristics of the subsurface that affect contaminant transport include adsorption of free product to the geological media of the unsaturated zone, permeability of the media, the size of the pore spaces, and the degree of water saturation. Major factors affecting the transport of released products in the unsaturated zone are summarized in Exhibit C-5. This section provides a brief description of each of these properties, followed by a discussion of the practical implication for the transport of products from exempt tank systems.

The viscosity of a fluid is a measure of its resistance to relative motion; the more viscous the fluid, the greater its resistance to flow. Gasoline is less viscous than water and, consequently, experiences less resistance to motion and can move more quickly through the unsaturated zone, all other things being equal. Heavier heating oils (e.g., fuel oil Nos. 4, 5, and 6) are substantially more viscous than water and tend to move much slower than water through the unsaturated zone. The viscosity of petroleum products is usually expressed as kinematic viscosity, which is absolute viscosity divided by density. Exhibit C-6 presents the kinematic viscosity for the petroleum products commonly stored in exempt tank systems. As a basis for comparison, water has a kinematic viscosity of approximately 1 centistoke.

Density is the weight of a substance per unit volume. A standard measure of density is specific gravity, which is the ratio of weight of a unit volume of the free product compared to pure water. Specific gravities for petroleum free products are given in Exhibit C-6. Denser chemicals will travel downward through the unsaturated zone faster than less dense compounds, all other things being equal.

Released petroleum products do not flow unobstructed in the subsurface environment because constituents of motor fuels and heating oils adsorb to the particles of the subsurface matrix and are retained. Field studies indicate that sorption characteristics of subsurface geological materials and different hydrogeological settings will significantly affect the retardation of the organic plume of contaminants as it moves through the subsurface (Mackay and Vogel 1985). Clay and organic matter are especially good substrates for adsorption. Many non-polar organic compounds, such as those that comprise the bulk of petroleum products, are likely to adsorb to the subsurface geological matrix.

The tendency of chemicals to adsorb to the geological matrix is closely correlated to the tendency of chemicals to partition to the organic phase when introduced to an aqueous/organic interface. The tendency to partition to the organic phase is measured by the K_{ow}, the octanol/water partition coefficient. Log K_{ow} values for petroleum free products are shown in Exhibit C-6; petroleum products have high K_{ow} values and, therefore, have a strong tendency to adsorb to the geological matrix. The tendency to adsorb is especially strong for the residual fuels, which have log K_{ow} values ranging up to 6. The large polynuclear aromatic hydrocarbons (PAHs) that are common in the residual fuel oils (i.e., fuel oil Nos. 4, 5, and 6) contribute to this strong tendency to adsorb to soil particles.

Exhibit C-5

MAJOR FACTORS AFFECTING TRANSPORT OF FREE PRODUCT IN THE UNSATURATED ZONE

FACTOR	DEFINITION	EFFECT
Viscosity	Resistance of fluid to relative motion.	Increases from gasoline, which is not viscous, to fuel oil No. 6, which is highly viscous and tends not to flow.
Adsorption	Tendency of free product to cling to soil and geological matrix.	Most petroleum free product will adsorb to particles, retarding or inhibiting flow.
Pore Size and Permeability	Size of pores in geological matrix and ability of free product to move through matrix.	Free product moves more easily through matrix with large pore spaces. Small pore sizes tend to retain free product.

Source: ICF Incorporated analysis.

EXHIBIT C-6

PHYSICAL PROPERTIES OF MOTOR FUELS AND HEATING OILS

	Boiling Range[a] (°C)	Kinematic Viscosity[b] (cST at 40°C)	Specific Gravity[a]	Solubility in Water (ppm)	Log Octanol /Water Coefficient[c]	Vapor Pressure[d] (mm Hg)
GASOLINE	50-225	0.5-0.65[e] (15°C)	0.72-0.76[e]	130[f]		465-773[g]
MIDDLE DISTILLATES						
Diesel Fuel	193-338	1.3-24.0	0.81-0.90	10-100[h]	3-4.5	1-10
Kerosene	175-325[h]	1.0-1.9[i]	-			90[j]
Fuel Oil No. 1	193-293	1.3-2.1	0.81-0.85	10-100[k]	3-4.5	1-10
Fuel Oil No. 2	282-338	1.9-3.4	0.88	7-10[l]	3-4.5	1-10
RESIDUAL FUELS						
Fuel Oil No. 4	101->588	5.5-24.0	0.90	1-20[m]	3-6	1
Fuel Oil No. 5	218->570	>24-168	0.94	1-20[m]	3-6	1
Fuel Oil No. 6	212->588	>92-638 (50°C)	0.97	2[l]	3-6	1

[a] Weiss 1981
[b] ASTM 1986
[c] USEPA 1985g
[d] Rose and Cooper 1977; values for the middle distillates were measured at 38 degrees Centigrade and for the residual fuels at 71 degrees Centigrade.
[e] Speight 1980
[f] Brookman et. al 1985a
[g] ASTM 1980
[h] NIOSH 1977
[i] Goodger 1975
[j] Litton 1977
[k] Neff and Anderson 1981
[l] Lu and Polak 1973
[m] Kolpack et al 1973; Neff and Anderson 1981

The permeability of the geological material and pore size also has major effects on the geometry of the release (i.e., the shape of the plume in the unsaturated zone). A highly permeable medium such as gravel or fractured rock will allow a release to move rapidly through the medium. In addition, the plume will tend to disperse as it flows through the pores and around the particles of the geological matrix. Media with very small pore spaces, such as clay, will severely impede the vertical flow of a release, causing the plume to spread horizontally.

As motor fuels and heating oils migrate through a porous medium, a certain amount will adsorb to geological material. Adsorption of some of the constituents in petroleum products is likely to be reversible. Many of the smaller and less hydrophobic compounds that adsorb to the geological materials will desorb after the contamination is gone, providing a continuing source of contamination after the source of the release has been removed. This phenomenon is especially likely to occur with the lighter aromatic fractions; larger hydrocarbon chain compounds from petroleum products are expected to be highly adsorbed to particles and will not desorb readily, if at all (USEPA 1985e).

As the plume of contaminants approaches the water table, the degree of water saturation in the vadose (unsaturated) zone increases. Because neither motor fuels nor heating oils are very soluble, they cannot occupy the pore spaces already occupied by the water. Increasing water saturation will decrease the permeability of the unsaturated zone to the released product, reducing the speed with which it reaches the water table, and increasing the horizontal spread of the contaminant plume.

For immiscible substances (i.e., liquids that are insoluble in water) such as fuel oils, the residual saturation of the free product, which is a measure of the retentive capacity of the soil with respect to a particular free product, is an important factor in estimating its spread. In general, permeability and retentive capacity of a soil are inversely related: less permeable soils retain more of an immiscible substance than do more permeable soils. Consequently, immiscible substances like fuel oils are likely to be highly retained (i.e., have a high residual saturation in the soil), which will help limit the spread of a plume of fuel oil. However, a high residual saturation means that more product remains in the soil after much of the free product plume has passed (CDM 1986).

In addition to chemical and geological factors, other site-specific factors affect the transport of released free product in the unsaturated zone. Rainfall can increase the infiltration of water through the unsaturated zone, where it will dissolve the water soluble components in the released product and increase their spread through the subsurface environment. Larger quantities of released free product are more likely to spread farther and faster than smaller releases. Manmade features, such as pipelines, sewers, and basements, also have the potential to facilitate movement of released product because of the porous materials (e.g., gravel) commonly used as backfill.

Implications

In general, heavier petroleum products with relatively high kinematic viscosities, such as fuel oil Nos. 5 and 6, will not penetrate soil as readily as the lighter petroleum products, such as gasoline, kerosene, and fuel oil No. 2. Exhibit C-6 shows that gasoline is less viscous than water, and the fuel oils have kinematic viscosities greater than that of water. As a result, heating oils tend to be less mobile in the subsurface environment than either water or gasoline.

As released petroleum products percolate through the soil, they are retained in pore spaces and as surface coatings on soil and rock particles because of adsorption. The depth of penetration of the petroleum product from the point of release into the geological matrix is directly related to its retention within the geological matrix and the release volume. Some geological matrices do not retain even highly viscous fuel oil very well. For example, a release of fuel oil No.6 from a 30,000-gallon fuel oil UST in Hasting, Minnesota, penetrated through fractured bedrock to a depth of at least 80 feet (ICF 1988).

Lighter heating oils (e.g., the middle distillates) will generally move farther and faster than the heavier heating oils (e.g., the residuals) because of their lower kinematic viscosities. For example, fuel oil No. 6 will move very slowly and is less likely to reach the saturated zone than fuel oil No. 2. Less permeable geological strata have the additional effect of spreading the plume horizontally, increasing the area of subsurface contamination but decreasing the amount of contaminant reaching the ground water. Gasoline, because of its higher mobility, is more likely to reach wells and will tend to contaminate a larger volume of an aquifer than will heavier petroleum products. Similarly, fuel oil No. 2 will tend to contaminate a larger area than fuel oil Nos. 4 or 6, all other things being equal. However, the concentration of fuel oil Nos. 4, 5, or 6 in the contaminated area may be greater, because the fuel oils will tend to be retained by the subsurface media and trapped in the pore spaces rather than being dispersed and diluted.

C.2.2 Transport of Free Product on the Surface of the Water Table

General Discussion

As released petroleum products travel downward through the vadose zone, they pass through zones of increasing water saturation. Eventually the products reach the surface of the water table, the boundary between the saturated and unsaturated zones. Because motor fuels and most heating oils are less dense than water and do not mix readily with ground water, they tend to spread out on top of the water table. When free oil initially reaches the ground water, its vertical movement is stopped where the pore spaces become saturated with water. As more released product reaches this region, a mound begins to form on the water table. If sufficient free product is present, then lateral spreading begins. Lateral migration ceases when the oil is at its residual saturation. The flow results in a characteristic shape that resembles a pancake (CDM 1986).

Some blends of fuel oil No. 6 are slightly more dense than water and do not float on the surface of the water table. The heavier fuel oils may slowly sink to the bottom of the aquifer where they may remain. Once at the bottom of the aquifer they are very difficult to remove except by excavation.

The shape of the floating contaminant plume depends largely on the permeability of the soil, the percolation rate, ground-water velocity, and the local water table configuration. In general, the more permeable the soil, the more the free product will spread laterally over the top of the ground water table. The steeper the hydraulic gradient (i.e., the tilt of the water table), the narrower the plume will be. The plume will also tend to be elongated in the direction of the ground-water flow and the elongation will be more pronounced where ground-water flow is fastest (CDM 1986).

Most of the factors affecting contaminant flow through the unsaturated zone will also affect the transport of the released products floating on the water table (Exhibit C-7). The free products with higher viscosity will be more attenuated and flow more slowly than less viscous products (e.g., gasoline). Heavy rainfall will cause the water table to rise, and the free product floating on the water table will be pushed upward toward the surface. Some of the free product will be retained in the pore spaces of the unsaturated zone after the water table returns to its previous levels.

Petroleum products are composed of many constituents with different physical and chemical properties that cause the constituents to travel at different speeds in the subsurface environment; therefore, contaminant plumes will separate as they flow on top of the ground water (Kerfoot and Sanford 1986). The movement of the heavier fractions are retarded by adsorption and retention in the capillary spaces, while the lighter fractions move faster and farther forming the leading edge of the plume. The lighter, more mobile fractions will form the leading edge of the plume and reach exposure points first, while the heavier, less mobile compounds will move slower and be less likely to reach exposure points.

Some of the less soluble constituents of the free product become trapped in the pore spaces due to capillary forces. Viscosity and insolubility of the free product are largely responsible for the retention of free product in the pore spaces. This retention is likely to be only marginally reversible, especially for heavier fuel oils, and greatly affects the kind of remediation activities that can be used for cleanup. Pump and treat options commonly used for releases of gasoline will not be useful for remediation at many fuel oil No. 6 releases; excavation will frequently be required to clean up contaminated subsurface soil.

The permeability of the subsurface environment will also greatly influence the horizontal movement of the contaminant plume. Both manmade and natural differences in the permeability can be significant. Manmade features like pipelines, wells, and basements can act as conduits for contaminant transport through the subsurface. Natural features like fractures in bedrock also

Exhibit C-7

MAJOR FACTORS AFFECTING TRANSPORT OF FREE PRODUCT ON THE SURFACE OF THE WATER TABLE

FACTOR	DEFINITION	EFFECT
Permeability	Tendency of free product to move through matrix.	The more permeable the soil, the more the free product will spread over the top of the aquifer.
Rainfall	Causes water table to fluctuate, forcing movement of free product in unsaturated zone.	Heavy rainfall will cause free product to rise toward surface.
Adsorption	Tendency of free product to cling to geological matrix.	Differences in adsorption cause free product to separate into components; lighter fractions move farther than heavier components.
Density	Weight of a substance per unit volume.	Generally, free product is less dense than water and tends to float.
Viscosity	Resistance of fluid to relative motion:	Increases from gasoline, which is not viscous, to fuel oil No. 6, which is highly viscous and tends not to flow.

Source: ICF Incorporated analysis.

facilitate subsurface transport. Clay deposits will have lower permeability and may cause irregularities in the shape of the plume.

Another important factor determining the extent of the spread of contamination is the volume of product released and the amount reaching the water table. The degree that petroleum product spreads on the water table is a direct function of the amount of product reaching the water table.

Implications

Motor fuels tend to spread farther on top of the water than fuel oils because of their lower viscosities. The size of the pancake formed by the fuel oils will decrease as the fuel oil number increases, all other factors being equal (e.g., fuel oil No. 2 will tend to spread farther than No. 4, which in turn will tend to spread farther than No. 6). An example of the extent of product spreading comes from a fuel oil No. 4 underground storage tank system in Saint Paul, Minnesota, which released 4,000 gallons of free product into the ground. Soil borings indicated a spill floating on the water table between 60 and 100 feet in diameter and between 13 to 20 feet deep (ICF 1988). Transport of a relatively viscous fluid like fuel oil No. 4 over a relatively large area demonstrates the potential for releases of free product to reach exposure points, such as wells or basements.

Manmade features of the subsurface environment are known to facilitate the transport of released petroleum products. In one incident, a release of fuel oil No. 6 from an exempt tank system in Laurel, Maryland, reached a sewer line, formed globules in the water, and traveled through a sewer to the Patuxent River (ICF 1988). Fuel oil No. 6 has also been reported to seep into basements situated near leaking underground storage tank systems, such as in Saint Paul, Minnesota, where it leaked from a 50,000-gallon tank to a nearby basement (ICF 1988).

Released petroleum products that are retained in the pore spaces are a continuing source of contamination (Kemblowski et al. 1987, Baradat et al. 1981). Fluctuations in the water table force the insoluble contamination retained in the pore spaces to move, leading to additional exposures. For example, in Long Prairie, Minnesota, fluctuating ground water has led to the discovery of additional contamination in subsurface soil after remediation was thought to have removed the contamination at a site (ICF 1988).

The heavier fuel oils and nonvolatile residual products retained in the pore spaces of the geological material are especially difficult to remove by pumping. Following a release in Falmouth, Massachusetts, nonvolatile residuals remained in the soil after the source of contamination, a leaking fuel oil No. 2 tank system, was removed and the ground water was being pumped and treated (Kerfoot and Sanford 1986). Even some fractions of kerosene, which is relatively mobile, are likely to remain in the ground after the more mobile fractions have been removed by pumping. Baradat et al. (1981) found light soluble aromatic components in a shallow ground-water well (less than 12 meters deep) after a kerosene spill, but the heavier and less soluble fractions did not appear in the water and were retained in a plume on top of the aquifer.

C.2.3 Transport in the Saturated Zone

General Discussion

The transport of product in the saturated zone depends primarily on two factors: density and solubility of the released product (Exhibit C-8). Because motor fuels and most heating oils are less dense than water, they tend to be found only in the uppermost parts of the saturated zone. The released substance typically takes the form of an emulsion at the interface between the water and oil phase. The rate of movement depends on the local ground-water gradients and the viscosity of the contaminants. Adsorption will retard movement of the more immiscible components. Some heavier No. 6 fuel oils will sink to the bottom of the aquifer because their density is greater than that of water.

Some fraction of the lighter products (e.g., gasoline, kerosene, and fuel oil No. 1) are soluble in water. Water solubilities for the free products are given in Exhibit C-6. Residual fuels generally contain few soluble constituents; soluble components of the lighter distillates will dissolve in the ground water at a rate determined by the extent of contact between the ground water, the free product, and the solubilities of the specific constituents. Rainwater seeping through the contaminant plume will also dissolve soluble components.

Once dissolved in the ground water, substances (primarily simple aromatic compounds) will move in the general direction of ground-water flow according to the mass transport laws of advection and dispersion. Advection is the movement of a contaminant plume in the direction of mean ground-water flow. Dispersion describes how a contaminant spreads out and is diluted as it occupies more of the saturated zone. Dispersion can be caused by a variety of factors, including molecular diffusion (the random movement of molecules of the dissolved product through the ground water), but the principal cause is generally variations in permeability of the geological material. Dilution caused by dispersion is an important means of lowering contaminant concentrations in the subsurface environment.

Implications

Transport of the components of motor fuels and heating oils dissolved in the water is a more significant problem for lighter products like gasoline and kerosene than for heavier fuel oils, because the residuals have fewer soluble components and these components tend to be present in much lower concentrations. In general, middle distillates have fewer water soluble components, and the concentrations of these dissolved components will be lower in the ground water. As with gasoline, the majority of the water soluble fraction of middle distillates is composed of aromatic compounds (USEPA 1985e). Residuals tend to have few constituents that are water soluble; concentrations of residuals in the ground water are usually less than 20 ppm, with polar and aromatic compounds comprising the majority of the soluble components (USEPA 1985b).

Exhibit C-8

MAJOR FACTORS AFFECTING TRANSPORT OF WATER SOLUBLE CONSTITUENTS IN THE SATURATED ZONE

FACTOR	DEFINITION	EFFECT
Density	Weight of a substance per unit volume.	Generally, product is less dense than water and will float. Fuel oil No. 6 may be more dense than water and sink.
Solubility	Tendency of a substance to mix with water.	Monoaromatic fraction (benzene and alkyl benzene), prevalent in gasoline, kerosene, and fuel oil No 1, is somewhat soluble and will dissolve in and will mix with ground water.

Source: ICF Incorporated analysis.

C.2.4 Transport of Vapors

General Discussion

Lighter petroleum products, such as gasoline, kerosene, and fuel oil Nos. 1 and 2, can enter the vapor phase in the subsurface environment. Major factors affecting the transport of vapors are summarized in Exhibit C-9. Volatility, the tendency to change into the vapor phase, is governed by vapor pressure and Henry's Law constant. Vapor pressure is relevant for assessing volatility of free product and provides an indication of the tendency of volatile compounds to pass into the gas phase from the contaminant plume. Henry's Law constant is a partition coefficient measuring the distribution of a substance between air and water and combines vapor pressure and solubility. Henry's Law constant, therefore, is a measure of a contaminant's tendency to volatilize from contaminated water. Once in the gaseous phase, the volatile components can move through the pore spaces of the soil. The contaminant will move by diffusion and advection, "blown along" by subsurface air currents (CDM 1986). Advection is controlled by fluctuations in barometric pressure, pressure gradients across building foundations, density differences between the air and vapor, and evaporation or chemical generation of vapor at a rate much greater than can be removed by diffusion alone (CDM 1986).

Molecules of gas may adhere to soil particles by adsorption, similar to absorption from the liquid phase. After the plume passes and concentrations in vapor are reduced, the adsorbed gas molecules may be released from the soil particles and move with the vapor again.

The size of the pore spaces in the unsaturated zone greatly influences the migration of volatile compounds in the soil (Karimi et al. 1987). Movement of soil gas may be blocked by imperious surfaces, such as geological barriers and manmade structures. Backfill materials used in construction are especially permeable to soil gases, and vapors are known to move easily along buried pipelines through the backfill (CDM 1986). Leaking underground storage tank systems have been detected by the smell of vapors in basements and by routine monitoring of vapors that reach the ground surface above the tank system.

Implications

Of the motor fuels and heating oils stored in exempt tank systems, the light and middle distillates are much more likely to have constituents that will evaporate in substantial amounts than the residual fuels. Vapor pressures of the free products are given in Exhibit C-6. Gasoline has a high vapor pressure, meaning that it has a large number of constituents with sufficient vapor pressures to evaporate in soils. Although fuel oil No. 2 also has constituents that are likely to evaporate, the heavy distillates and residuals do not have volatile components that are likely to be transported with soil gases. Little field data are available to estimate the potential effects of vapor transport of petroleum products. Alkyl benzene and some normal alkanes have been reported in soil gas samples after a fuel oil No. 2 spill in Falmouth, Massachusetts (Kerfoot and Sanford 1986). The Barnstable

Exhibit C-9

MAJOR FACTORS AFFECTING TRANSPORT OF VAPORS

FACTOR	DEFINITION	EFFECT
Volatility	Tendency of solid or liquid to enter vapor phase.	Lighter products (e.g., gasoline, fuel oil No. 2) will enter vapor phase in subsurface environment.
Pore Size	Size of pores in geological matrix.	Larger pore size facilitates transport of vapor in subsurface.
Adsorption	Tendency of vapor components to cling to geological matrix.	Similar to liquids, vapor may adsorb, increasing the amount of product retained in subsurface.

Source: ICF Incorporated analysis.

County (Massachusetts) Health and Environmental Department is developing a leak detection program for exempt tank systems by monitoring the presence of vapors from heating oil in the soil (Stiefel and Heufelder 1987).

C.2.5 Fate Processes

General Discussion

Several mechanisms influence the retention of petroleum products in the subsurface environment and the hazard posed by a release (Exhibit C-10). Dispersion and dilution, while not destroying the released constituents, may reduce their concentrations to undetectable levels. Adsorption to geological materials and retention in the pore spaces may trap product in the subsurface indefinitely. Constituents may be transferred to another medium, such as volatilization to air or release to surface water, reducing their subsurface concentrations but possibly creating new environmental problems in other media. Another mechanism, biodegradation, is a fate process that can reduce the concentration of contaminants in ground water over time.

Dispersion and dilution can reduce concentrations of free products in ground water. These processes are not ultimate fate processes in that the products are still present, but concentrations may be reduced to such low levels that they cannot be detected.

Adsorption and retention in pore spaces increases the amount of time that products will remain in the subsurface environment. Some compounds may be essentially irreversibly bound or trapped in pore spaces. These compounds will be highly resistant to release and may remain trapped in the subsurface by these mechanisms indefinitely. In other situations, adsorption simply separates the plume into fractions of differing mobilities. Heavy metals in the products may also bind to particles by ionic exchange and become immobilized.

Transferring contaminants to other media, such as air and surface water, reduces the volume of contaminant in the ground water. Volatilization can remove the contaminants from the subsurface environment by transferring it to the air. Once in the air, constituents of release may be destroyed by sunlight (i.e., photodegrade) or may become dispersed and diluted in the air so that they are no longer present in measurable concentrations. When released to surface water, product constituents are subject to a variety of processes that may reduce their concentration. Contaminants may be diluted to unmeasurable concentrations, adsorb to particles and remain in the sediments, or photodegrade and biodegrade.

Biodegradation is an important fate for some constituents of products released from exempt tank systems. Several factors will affect the likelihood and rate of biodegradation. These factors include temperature, pH, oxygen level, moisture content, nutrient levels, microbiota concentrations,

Exhibit C-10

MAJOR FATE PROCESSES

PROCESS	EFFECT
Dispersion and Dilution	Reduce product concentrations by spreading it over larger area.
Adsorption and Retention	Irreversible binding will retain product in subsurface indefinitely.
Transfer to other Media	Removes product from subsurface to air or surface water, transferring problem to other media.
Biodegradation	Some products will be degraded by microorganisms living in the subsurface environment.

Source: ICF Incorporated analysis.

contaminant concentrations, and previous exposure of the microbiota to contaminants (Mackay and Vogel 1985). The variation and interactions of these factors make it difficult to generalize about the biodegradation potential of any particular product. Brookman et al. (1985b) has noted the difficulty in predicting biodegradation based on laboratory studies, and field studies are rare.

The potential for products released from exempt tank systems to biodegrade depends strongly on the specific contaminants involved. In general, researchers have found straight chain paraffinic hydrocarbons are the most susceptible to degradation, and aromatics are the least degradable. Examination of the susceptibility of hydrocarbons in weathered fuel oil Nos. 2 and 6 to microbial degradation revealed less degradation of No. 6 (Atlas 1981). Even identical compounds were less degraded in fuel oil No. 6 than No. 2, presumably because of the interaction with other constituents. Some degradation was reported when fuel oil No. 6 was applied to topsoil (Kincannon 1974). However, the microbial populations at the top surface of the soil are much different than those in the subsurface, partly because the levels of nutrients and oxygen are lower in the subsurface environment, thereby reducing the rate of biodegradation. Consequently, studies such as this indicate a maximum potential biodegradation, rather than an expected level of biodegradation in the subsurface.

In another surface soil study, only about 50 percent of the fuel oil No. 6 was degraded after a year under ideal degradation conditions (Raymond et al. 1976). This study indicated that all classes of hydrocarbons would degrade, but that nonpolar hydrocarbons degrade much slower than other hydrocarbons. Studies on marine organisms, which are not a direct indication of subsurface microbial activities but do give a general idea of inherent biodegradability of the petroleum products, indicate that straight-chained paraffins and aromatic compounds are the first to degrade and that many of the compounds most resistant to degradation were branched and cyclic aliphatic hydrocarbons (Pierce et al. 1975).

Researchers, such as McKee (1972), Davis (1972), and McCarty et al. (1984), have found that biodegradation is most likely to occur where oxygen is plentiful (i.e., closer to the surface or nearer aerated ground water). Abundant oxygen is especially important in limiting the spread of simple aromatic compounds that are somewhat soluble, like benzene, toluene, and xylene, as well as those that are degraded by microorganisms requiring oxygen to survive (i.e., aerobic microorganisms). Biodegradation by aerobic microorganisms was thought to have accounted for reductions in the concentrations of aromatic compounds after source removal, but before source remediation in a leak of fuel oil No. 2 (Kerfoot and Sanford 1986).

Implications

Available information suggests that gasoline will be the most degradable of the petroleum products and fuel oil No. 6 will offer the greatest resistance to degradation. Biodegradation can limit the spread of the soluble aromatic fraction of gasoline, which is associated with the greatest health risk. Those heavier fuel oils will not be readily biodegradable, however, because the biodegradation of those fuel oils is inhibited by the large size and insolubility of their constituent molecules. Even kerosene is expected to remain largely in the ground (Baradat et al. 1981). Thus, untreated contamination from heating oils will remain in the subsurface environment longer than contamination from gasoline.

Transfer of released petroleum products from the subsurface to surface water has been reported many times. In one situation, 500 gallons of fuel oil released from an exempt tank system accumulated on the surface of a small lake near Park Rapids, Minnesota (ICF 1988). In another situation, 200 to 300 gallons of heating oil leaking from an underground storage tank system in Crookston, Minnesota, entered a sanitary sewer and contaminated the Red Lake River (ICF 1988). In these cases, not only was soil and ground water cleanup necessary, but actions had to be taken to prevent the spread of contamination on surface water as well.

C.3 HAZARD POTENTIAL

Previous parts of this appendix have examined (1) the composition of petroleum products and the adverse health effects that may be associated with exposures to the fuels and their constituents and (2) how the petroleum products released from underground storage tanks may be transported through the environment and contaminate soil and ground water. This last section discusses the possible ways in which humans may come into contact with the contaminated media, and the hazards that may be associated with those exposures.

Humans may be exposed to petroleum products released from underground storage tank systems through contact with contaminated air, soil, surface water, or ground water. The most likely means of human exposure to the water-soluble components of petroleum products from underground tank systems is contact with contaminated ground water. Such exposures can occur through consumption of contaminated water, absorption through the skin during bathing or washing, and inhalation of volatilized components during showering. Exposure can also occur when motor fuels and fuel oils seep into basements of residences and commercial establishments. Contact with fuels pooled in basements may result in absorption of the substance through the skin. Significant exposures can also result when accumulated vapors from seepages are inhaled; however, this exposure route is important only for the more volatile fuels, such as gasoline and kerosene, and, to a lesser extent, diesel fuel and fuel oil No. 2. Seepages may also result in a buildup of explosive vapors and put persons and property at risk of explosion or fire. Human exposure to contaminated surface water is less of a threat than other types of exposure, because the potential contamination is more likely to be readily visible and avoided.

Humans can also be exposed through contact with contaminated soil. Soil can become contaminated when fluctuations in the water table cause released petroleum products to rise to the surface. Releases have been detected when dead patches appear in grass or other surface vegetation. Contaminated soil may also be brought to the surface during excavation of an area during cleanup of a release.

High concentrations of contaminants in ground water and ambient air are likely to be detected by taste or smell, and in many cases, corrective action may be taken before long-term health effects are observed. Because low level contamination is likely to go undetected, however, extended exposures to low levels of contamination may pose a long-term threat to human health.

Each of the main categories of heating oils (middle distillates and residual fuels) poses different health risks based on their toxicities (Exhibit C-2) and their ability to be transported through the environment to places where human may encounter them. These health risks are summarized below.

C.3.1 Gasoline

Gasoline moves relatively easily through the environment, making contamination of ground water by gasoline released from underground storage tank systems likely. Long-term inhalation of gasoline vapors has been associated with cancer, which may be caused in part by benzene. Risks from releases from exempt motor fuel tank systems are less than risks from releases from regulated motor fuel USTs, however, because the capacity of these exempt tank systems and the potential quantity released is smaller.

C.3.2 Middle Distillate Fuels

The middle distillate fuels move fairly easily through the environment and releases of these fuels can be expected to contaminate ground water. Diesel fuel and fuel oil No. 2 have been shown to be weak to moderate carcinogens when painted on the skin of laboratory animals, and several other components of the middle distillates are known to have adverse health effects. The chemicals of greatest concern include toluene, xylene, and PAHs. Toluene and xylene are present at much lower concentrations in middle distillates than those found in gasoline, but may still be of concern. A noncarcinogenic PAH, naphthalene, is present in the middle distillates in significant concentrations and may pose a health risk when dissolved in ground water, even in low concentrations. Two PAHs, benzo(a)pyrene and benzo(a)anthracene, have been detected at very low concentrations. These compounds are generally less water soluble than toluene and xylene, but they are probable human carcinogens. The constituents of middle distillates, however, have not been well studied and it is likely that the compounds listed above are not the only toxic constituents of these fuels; consequently, the toxicities of these compounds may not be representative of the true toxicity of the middle distillates.

C.3.3 Residual Fuels

The residual fuels, fuel oil No. 6 in particular, contain higher concentrations of PAHs than middle distillates. Residual fuels may also contain blending agents that have been shown to be potent carcinogens in animals. The residual fuels are very viscous, however, and it is unlikely that a significant quantity of the fuel would reach drinking water wells. In addition, the low water solubilities of most constituents of residual fuels make it unlikely that an aquifer would become extensively contaminated. However, there have been reports of fuel oil No. 6 reaching water tables and contaminating ground water. The extent of the contamination is unknown. Therefore, while the potential for ground water contamination by residual fuels is not as great as for the middle distillates, the potential for such releases exists. These fuels may contain potent animal carcinogens and, therfore, these releases may pose a threat to human health.

In conclusion, releases of middle distillate fuels, and to a lesser extent, residual fuels leaking from underground storage tank systems can contaminate ground water. In addition, leaks of the lighter middle distillates may seep into basements and release potentially explosive vapors. The health risks associated with releases of the middle distillate fuel oils may be significant; those associated with releases of the residual fuel oils are believed to be less, but still of concern because of the presence of PAHs and a variety of blending agents shown to be carcinogenic in animals.

APPENDIX D

SOURCES OF STATE AND LOCAL STATUTES AND CODES

Arizona:	Arizona Revised Statutes, sec. 36-3301.11.
California:	California Health and Safety Code, sec. 25281(r).
Connecticut:	Regulations of Connecticut State Agencies, sec. 22a-449(d)-1(a).
Delaware:	Delaware Code, Chapter 74, Title 7, sec. 7406.
Florida:	Florida Statutes, Chapter 376, sec. 376.301(4).
Hawaii:	Hawaii Revised Statutes, sec. 342-61.
Illinois:	Illinois Administrative Code, Subtitle G, Chapter I, Subchapter d, Part 731.101(d).
Iowa:	Iowa Administrative Code, Chapter 135, sec. 455B.471.6.
Kansas:	Kansas Administrative Regulation, Article 28-44.
Kentucky:	Kentucky Revised Statutes, sec. 224.810(1).
Louisiana:	Code of Regulations, Title 32, Part XI, Chapter 3, sec. 305.
Maine:	State of Maine, 38 MRSA 562(13),(14).
Maryland:	Code of Maryland Regulations, Title 8, Subtitle 5, Chapter 4, sec. 09.
Massachusetts:	Code of Massachusetts, Volume 15, Title 527, sec. 9.00.
Michigan:	Michigan Compiled Laws, Chapter 23, sec. 13.29(71).
Minnesota:	Minnesota Code, sec. 116.47.
Montana:	Montana Code, sec. 75-10-403(17).
Nebraska:	Nebraska Revised Statutes, sec. 81-15, 119(7).
New Hampshire:	New Hampshire Code of Administrative Rules, Part Ws 411.
New Jersey:	New Jersey Code, sec. 58:10A-22.p.
New Mexico:	New Mexico Code, sec. 74-4-3.

U.S. Environmental Protection Agency (USEPA). 1985e. Information Review of Petroleum Middle Distillate Fuels (Draft Report). Prepared under EPA Contract No. 68-01-6650. IR-470. March 15, 1985. TSCA Interagency Testing Committee, Washington, DC.

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U.S. Environmental Protection Agency (USEPA). 1986b. Superfund Public Health Evaluation Manual. Office of Emergency and Remedial Response, Washington, DC.

U.S. Environmental Protection Agency (USEPA). 1986c. Health and Environmental Effects Profile for Xylenes (o-, m-, p-). Prepared for the Office of Solid Waste and Emergency Response, Office of Air Quality Planning and Standards, and Office of Air and Radiation, EPA. Prepared by Environmental Criteria and Assessment Office, Cincinnati, OH and Research Triangle Park, NC.

U.S. Marine Corps (USMC). 1986. Personal communication with Laura Huber and Captain Hilliker by SCS Engineers of November 21, 1986.

U.S. Navy (USN). 1986. Personal communication with Elizabeth Ford and Brian Collins by SCS Engineers of December 10, 1986.

Weiss, G. 1981. Hazardous Chemical Databook. Noyes Data Corporation, Park Ridge, N.J.

Wisconsin Department of Industry, Labor, and Human Relations. 1987. UST Notification Data Base. February 6, 1987.